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Constructive simulations are currently being used in the defense industry as part of the acquisition process to design new weapon systems. Constructive simulation can also be used to answer questions on how to tactically employ this new system early in the systems acquisition process. The goal of this research is to develop one methodology of exploring tactics concurrently with the development of the weapon system. The research uses the development of a Future Scout Vehicle and a basic difference in reconnaissance tactics as a demonstration of this method. This research is not primarily concerned with answering the question of which particular vehicle or tactic is the best choice, instead, it develops and demonstrates a method of comparing the two factors using ModSAF, a constructive Simulation.

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EVALUATION OF LAND RECONNAISSANCE TACTICAL BEHAVIORS EARLY IN THE SYSTEMS DEVELOPMENT OF A NEW WEAPON SYSTEM USING CONSTRUCTIVE SIMULATION

by

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B.B.A, Texas Agricultural and Mechanical University, 1988.

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Department of Industrial Engineering and Management Systems
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ABSTRACT

Constructive simulations are currently being used in the defense industry as part of the acquisition process to design new weapon systems. Constructive simulation can also be used to answer questions on how to tactically employ this new system early in the systems acquisition process. The goal of this research is to develop one methodology of exploring tactics concurrently with the development of the weapon system. The research uses the development of a Future Scout Vehicle and a basic difference in reconnaissance tactics as a demonstration of this method. This research is not primarily concerned with answering the question of which particular vehicle or tactic is the best choice, instead, it develops and demonstrates a method of comparing the two factors using constructive simulation.

ModSAF is in use by governmental and defense industry entities to conduct testing on future weapons systems. Primitive elements of small unit or entity tactics have been programmed into the code of the simulation to allow for simple automated response to the simulated battlefield environment and other entities, both friend and foe. However, the idea of changing the behavior of entities to better utilize new weapon systems capabilities provides an interesting look at a potential use of simulations.

Constructive simulation can be used to explore the relationship between doctrine and potential weapons systems early in the acquisitions process. In this research, a case study is formulated and examined that relates the development of land forces reconnaissance tactical behavior concurrently with the acquisition of a new land force reconnaissance vehicle. This experiment provides insight into the interaction or lack of interaction, between selected different future scout vehicle variants and passive and aggressive reconnaissance behaviors in a particular scenario.

A 2 x 2 factorial experiment was used to compare the interaction of vehicle type and tactic used. The results of the research provide insights that were both expected and somewhat surprising. Some of the results of this research led to interesting topics for further study. While the results were not conclusive, the goal of demonstrating an analysis using constructive simulation was met.

This work is dedicated to the men of Task Force Smith, 1-21st Infantry Regiment and 52nd Field Artillery Battery, who at 7:30 A.M. July 5 1950 joined in battle with a North Korean force in the Republic of Korea. They entered battle with equipment that was inferior to that of the enemy, with inadequate training, and with an incomplete knowledge of the enemy's capability-- and they suffered greatly. May simulation never cause our solders to enter battle with an inadequate, untrained, or uninformed force in the future.

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CHAPTER 1

MILITARY DOCTRINE DEVELOPMENT AND SIMULATION

1.1 Introduction to Doctrine and Tactics

Generals throughout history have used doctrine to assist in the command and control of their armies, to maneuver and engage the enemy, and in the end, meet their government's political objectives. Early doctrine was not complicated, as the numbers of soldiers was small and the types of weapons were simple. The military leader led his unit into battle. The soldiers could see and hear all that the leader did, and they emulated him.

Time and technological advances have led to the development of more complex weapons, command and control structures, and battle has increased in range well beyond visual and audio range. Military doctrine has changed with time to account for these advances.

Military doctrine is a set of rules or principles that govern the conduct of a military unit. The doctrine could be a set of instructions that gives an inexperienced leader a template of behavior to set into motion given a certain set of circumstances. It can explain the underlying principles of the action or tell the leader exactly what physical formation to use and how far apart each vehicle should be from the other in the same formation.

According to United States Army Field Manual (FM) 100-5, Operations,

> Doctrine is the statement of how America's Army, as part of a joint team, intends to conduct war and operations other than war. It is the condensed expression of the Army's fundamental approach to fighting, influencing events in operations other than war, and deterring actions detrimental to national interests. As an authoritative statement, doctrine must be definitive enough to guide specific operations, yet remain adaptable enough to address diverse and varied situations worldwide. (Headquarters, Department of the Army (HQDA) (b), 1995, p.145)

According to Joint Publication 1-02 DoD Dictionary of Military Terms, "Doctrine is the fundamental principles by which military forces or elements thereof guide their actions in support of national objectives. It is authoritative but requires judgement in application. Doctrine provides broad guidelines for action. Tactics and techniques flow from and implement doctrinal principles" (Headquarters, Department of Defense (DoD) (a), 1995, p.140).

At lower levels of military operations, doctrine enforces standardization between units and reinforces simplicity in training. Of course, the goal of training for military units is to maximize tactical advantage on the battlefield, but how to do so with mass conscripted armies or modern semi-professional armies in the least amount of training time is now of practical necessity.

As new weapon systems are developed, new doctrine is established. Many times the doctrine is the result of lessons learned in actual combat with older systems used in the last conflict. This doctrine may survive for many years and many weapons systems changes until a new conflict comes along to introduce new problems to be solved. The introduction of anti-tank guided missiles (ATGM) into modern war is an excellent example. Up until the 1973 Arab-Israeli war, Israeli had become a master of tank

warfare, using massed formations of tanks to decimate Arab armies. Things change, however, as is evident in the words of one Israeli tank commander,

> We were advancing [attacking an enemy force], and in the distance I saw specks dotted on the sand dunes. I couldn't make out what they were. As we got closer, I thought they looked like tree stumps. They were motionless and scattered across the terrain ahead of us. I got on the intercom and asked the tanks ahead what they made out of it. One of my tank commanders radioed back, "My God, they're not tree stumps they 're men." What were men doing out there—standing quite motionless—when we were advancing in our tanks towards them? [After the 1967 war, Israeli tank doctrine called for massed tank attacks, especially against infantry forces, unsupported by tanks.] Suddenly all hell broke loose. A barrage of missiles was being fired at us. Many of our tanks were hit. We had never come up against anything like this before. (Isby, 1981, p.145)

The advent of ATGM's forced the Israeli's to adopt a different doctrine. They had to use a combination of tanks; infantry, artillery and tactical aircraft, to defeat the ATGM threat and eventually win the war, but not without tremendous losses (Isby, 1981, p.146).

The United States Army is currently undergoing a revolution in command and control (C^2) technology that is certain to change the way we fight. Capitalizing on digital technology, the new C^2 systems, like Forward Battle Command Brigade and Below, or FBCB2, allows leaders and commanders to "see the battlefield" on a computer generated map screen, as the battle unfolds.

The Army's effort for developing doctrine in the post-cold war era is outlined in the U.S. Army's Training and Doctrine Command (TRADOC) pamphlet 525-5, *Force XXI Operations.*

> The Army's baseline work in evolving a twenty-first century doctrine was the creation of the 1993 version of FM 100-5. That doctrine was designed to address the much broader range of missions facing the Army today. It began our change,

> shedding our Cold War thinking that was so necessary to victory then, but in need of expansion now. It must serve as a catalyst for change, explaining that change in a language that all soldiers and leaders can fully understand. The major thrust in future doctrine development will be living doctrine based on a fluid, strategic environment, lessons learned from ongoing operations, emergence of new warfighting technologies, and results of simulations and battle lab experimentation.
>
> Simulations and experiments through battle laboratories will continue to serve changing requirements of emerging doctrine, helping Force XXI conduct the critical, doctrinally focused front-end analyses required for new materiel and force design initiatives. As Force XXI refines new ideas and concepts, their doctrinal relevance will be quickly captured in manuals and ultimately through CD ROM-type (compact disk read-only memory) technology-communicated throughout the Army. Key to this timeliness will be electronic staffing whereby Army learning and combat training centers, major commands, doctrine developers, operational planners, and subject-matter experts will form an internetted system for the development of relevant doctrine.
>
> Versatility will be a key characteristic of future doctrine. With the advent of wider roles and missions in the future, Force XXI will have to interface with other services, foreign forces, government, and even non-government agencies in doctrine development. The critical importance of developing doctrine for multinational operations-tailored for traditional allies and even likely coalition partners-will require command emphasis. The expanding scope and unpredictable nature of future military operations make doctrinal initiatives along these lines essential for success in war and OOTW. (HQDA (a), 1995, p.4-1)

New weapons systems are also being developed that greatly extend the lethality and detection ranges of modern military units. If history is any judge, these developments will require new doctrine to maximize their benefits while minimizing their weaknesses. Developing these doctrines could require years of practice and modification by units with the actual weapons, or like the Israeli example, could be the result of the loss of soldiers' lives or equipment in battle.

1.2 New Weapons Doctrinal and Tactics Development in the U.S. Army

The U.S. Army develops new weapons systems concepts in a systemic fashion. The US Army Training and Doctrine Command (TRADOC) is responsible for all force changes in the Army. According to TRADOC Pam 71-9, Requirements Determination, a need for a change is first established in its Mission Needs Statement (MNS). This document recognizes the deficiency in one of six categories: Doctrine, Training, Leadership Development, Organization, Materials, Soldier Systems (DTLOMS). A selected TRADOC force developer then conducts an analysis of alternative courses of action to correct the deficiency identified in the MNS. This analysis may uncover the need for a change in any or all of the DTLOMS areas (HQDA (b), 1998, pp.2.2-2.7).

This need may be for a new weapon system or for new tactics, techniques, and procedures (TTP) that are required for the force. Doctrine may change for many reasons. A TTP change may come from experience in the force in combat or in training. TTP may come from Army leaders involved in teaching doctrine at an Army school or at a CTC. [Combat training center] It may come from the development and fielding of a new weapon system. It may come from the introduction of a new enemy capability that threatens existing doctrine. Doctrine may also be changed on a cyclical basis, allowing for a periodic review of TTP in a systemic fashion (HQDA (b), 1998, pp.2.2-2.7).

Once the need for doctrinal change is established, a process of evaluation is set in motion. This research will use the doctrine of US Army Armor/Cavalry branch to explain the process used in the Army. The US Army Armor Center in Ft Knox, KY is the proponent for Army armored fighting vehicles. The Armor Center is divided into three

directorates that are involved in the development of mounted warfare force changes. The directorate of Force Development (DFD), Training and Doctrinal Development (DTD), and the Mounted Maneuver Battlespace Lab (MMBL) are responsible for the development of new mounted warfighting concepts, doctrine and weapons systems. DFD and the MMBL are focused on emerging DTLOMS and the DTD focuses on current doctrinal development. DTD also supports and plans for long range changes in DTLOMS. See Appendix C for a complete interview transcript with COL Gunzelman, the commander of the MMBL (Gunzelman, 1998).

1.3 Development of New Weapons Systems

Once a need is identified, an Integrated Concept Team is formed to study the problem and produce a Requirements Document. The Integrated Concept Team (ICT) has members from all three directorates at Ft Knox. If a material system is involved the ICT includes members from the U.S. Army Material Command (AMC). In the Material requirement area, the Mission Needs Statement leads to an Operational Requirements Document. The force developer leads the ICT in the exploration of the concept behind the need for a new system. The exploration often includes all forms of simulation-virtual, constructive and live. At FT Knox, the simulation support comes from the MMBL.

1.4 Mounted Maneuver Battlespace Laboratory Simulation Support

The United States Army is currently involved in the process of defining its role in national defense through the next fifty years. TRADOC Pam 525-5 states, " Simulations and experiments through *battle laboratories* will continue to serve changing requirements

of emerging doctrine, helping Force XXI conduct the critical, doctrinally focused front-end analyses required for new materiel and force design initiatives" (HQDA (a), 1995, p.4-1).

According to the Headquarters, Department of the Army, Deputy Chief of Staff, Combat Developments Battle Lab web site,

> There are 11 such battle labs designed to define doctrine. The Battle Labs were formed as a means for the TRADOC to streamline its mission of identifying concepts and requirements for new DTLOMS. The dynamic nature of change, however, has continued to tighten the need for teamwork between concept development, requirement generation, solution development and operational testing. It involves not only TRADOC, but also the Department of the Army Staff, the U.S. Army Material Command (AMC), the U.S. Army Operational Test and Evaluation Command and operational forces around the world. Today, Battle Labs, though still an integral part of TRADOC, are staffed with representatives of all the agencies mentioned. Likewise, since warfighting is inherently joint in nature and potentially worldwide in scope, the Battle Labs Program encourages participation from other Services and allies in its activities. (HQDA (c), 1998, p.1)

The lab concerned with US Army ground tactical reconnaissance operations is the Mounted Maneuver Battlespace Lab located in Ft Knox, Kentucky. The research included as interview with the director of the Mounted Maneuver Battlespace Laboratory (MMBL), COL Karl Gunzelman. The interview objective was to determine if the US Army uses constructive simulation in the development and evaluation of tactics, techniques, and procedures (TTP) of new weapons systems and how it is currently used. There was also two sub objectives:

- To determine the current method for developing TTP the Army uses.
- To determine if constructive and virtual simulations are used in cooperation to develop and evaluate TTP.

To proof the interview questionnaire, the author conducted two interviews with CPT Dan Ray and CPT Sean Pritchard. Both of these captains are assigned to the MMBL and are participate in the conduct of virtual experimentation on evolving weapons systems and tactics.

The results of the interview with COL Gunzelman are located in Appendix C. In the interview, he confirmed the fact that all three forms of simulation--live, constructive, and virtual--are in use in the MMBL. They are used in support of ICT requirements analysis and for the development of new concepts of warfighting. Experiments are also conducted to aid the fiscal decisions of Army leaders, like a recent analysis of the capabilities of a three or four tank platoon.

COL Gunzelman reinforced that the MMBL used virtual experiments more extensively in the experiments that included tactics and behaviors. His reason was the ability to get more realistic human behaviors out of human players than the current constructive models (Gunzelman, 1998).

1.5 Directorate of Training and Doctrinal Development Uses of Simulation

There was also an interview conducted of a senior doctrine writer at the DTD at Ft Knox. MAJ Phil Johnson is the author of FM 71-3, Armor and Mechanized Infantry Brigade Operations. MAJ Johnson confirmed that (1) simulations were used in the tactical doctrine and material development of a new weapon systems and (2) constructive representations are not designed specifically in conjunction with the development of new weapons systems. MAJ Johnson mentioned that DTD doctrine writers change frequently over the long life cycle development of a new weapons system. Generally, the tactical

manuals at brigade and below levels are updated every three years. A weapon system can take up to five or ten years to develop. The doctrine writers that work on the requirements phase of a new system are usually not the same writers that update the tactics based on the introduction of the system to the force. This is a challenge to doctrine writers, like MAJ Johnson, to keep the results of simulation experiments available to future doctrine writers. See Appendix C for the full interview transcript (Johnson, 1998).

1.6 Weapon System and Tactics Development

Based on these remarks, current weapons system development appears to progress in at least two separate worlds. The development of the best characteristics of a system are analyzed and the best tactics are then studied to use these systems. Constructive simulation is often used in the development of vehicle characteristics and virtual simulation is used to study the tactics in a sequential fashion. In some major weapon systems, the tactics developers use both types of simulation to study tactics, but are studying the effects of the tactics well after the vehicle is in service (HQDA (a), 1998 Sept-Oct, pp.44-47). That creates the query, would the study of vehicle characteristics and tactics concurrently using constructive simulation early in the systems engineering process benefit the process?

1.7 Comparison of behaviors using Simulation

While undoubtedly, the next war will necessitate the modification of tactics, based on the uncertainties of war; there may be a way to speed up the doctrinal development process, or perhaps improve upon it through computer simulation.

Simulations are currently being used in the defense industry as part of the government acquisition process to design new weapon systems. Experiments have also been done on testing future weapons systems using computer-generated forces at the Institute for Simulation and Training in Orlando, FL. One such study found that Computer Generated Force (CGF) systems could be used for evaluating future systems, but that it is a complex process. The authors concluded that the CGF has to be altered to support the system to be tested, and a variety of scenarios must be developed and implemented, measures of effectiveness (MOE) are needed for the scenarios and enough experimental runs are needed to determine statistically significant results (Craft and Karr, 1996, p.13).

One CGF model, Modular Semi-Automated Forces (ModSAF), is in use by governmental and defense industry entities to conduct testing on future weapons systems. Simple doctrine of small units, or entities, has been programmed into the code of the simulation to allow for simple automated response to the simulated battlefield environment and other entities, both friend and foe. For example, ModSAF entities have the ability to use limited terrain reasoning for route selection based on the vehicle's

physical characteristics and models. ModSAF has been modified in certain labs to model scout reconnaissance behavior more efficiently, as part of the development of a future scout vehicle (FSV). However, the idea of changing the behavior of entities to better utilize new weapon systems capabilities provides an interesting look at a potential use of simulations (Lartigue, 1998, pp.110-111).

One interesting question in the area of simulations is "How much intelligence in CGF is enough?" In a recent thesis on the introduction of intent as a MOE in reconnaissance behavior, Lartigue alluded to the necessity of further refining the new scout vehicle model by behavior modification of the individual in ModSAF. Lartigue refined the ModSAF behavior of the individual scout vehicle to "act" as a scout might in a given tactical situation. He did not, however, focus on the analysis of the behaviors of the entities in cooperation with each other or as a unit using theoretical tactics—reconnaissance behaviors based on the new capabilities on the FSV.

According to Lartigue's work,

> The [Tracer Recon] behavior does account for differences in variant composition in the sense that it cues available sensors to gain intent...The behavior does not allow for specific tactical employment variations based on some vehicle strengths and weaknesses...The modification of the behaviors based on capabilities would be an interesting and appropriate area of further research. (Lartigue, 1998, pp.66-67)

How might the new weapon system tactical unit behavior developed concurrently with the new weapon system design take full advantage of that system design to enhance the tactical outcome? This research proposes to explore the concept of using constructive simulation to simultaneously develop and evaluate both new small unit tactical doctrine

in light of a new weapon's increased capabilities. The next chapter explores the literature to answer two questions that arise from this proposal:

- Has the military developed tactical doctrine and new weapon system design concurrently before?
- What type of simulation have they used?

CHAPTER 2

ANALYZING MILITARY BEHAVIOR USING CONSTRUCTIVE SIMULATION

"The evaluation of a weapons system (or a simple vehicle or tactic) can be made by using virtual simulation based evaluations early in the acquisition process without endangering people, disturbing the environment, or huge expenditures." (Craft and Karr, 1996, p.13)

2.1 Constructive Simulation as an Analysis Tool

Computer simulation "refers to methods for studying a wide variety of models of real-world systems by numerical evaluation using software designed to imitate the system's operations or characteristics, often over time" (Kelton, Sadowski, Sadowski, 1998, p.7).

As defined by DoD Directive 5000.59, constructive simulation is "...Models and simulations that involve simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes." Simulations are also known as a "method for implementing a model over time. Also a technique for testing, analysis, or training in which real world systems are used, or real world and conceptual systems are reproduced by a model." A model is defined as,

"...a physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process" (DoD (b), 1995, pp.123, 129).

Much work has been done in the analysis of new weapons systems using computer simulations. Constructive simulations are often used to conduct this analysis. There are many such simulations in use today. The U.S. Army uses JANUS to train battalion and company level officers. According to the National Simulation Center, " Janus is an interactive, event-driven wargaming simulation used to train platoon and company level commanders on the application of tactical doctrine and combat techniques.... At the battalion and brigade level, Janus serves as an excellent training simulation requiring detailed Commander-S2/S3 interaction as they develop and execute the ground tactical plan."

Another simulation, Corps Battle Simulation (CBS), is used to train division and corps staff officers and commanders. One constructive simulation, mentioned in the previous chapter, which is widely used in the acquisition process is Modular Semi-Automated Forces (ModSAF).

2.2 Recent Uses of Simulation as an Analysis Tool

Both Janus and ModSAF have been used extensively to show differences between existing systems and new improved systems that were designed to replace them. Two examples of the use of Janus as an analysis tool are an experiment comparing the Bradley M2A2 and the improved M2A3 and an analysis of the FSV. (Lovaszy, 1996) (Savetti, 1994)

Mod SAF has also been used in the acquisition process. According to ModSAF: Software Architecture Design and Overview document, "ModSAF is a Computer Generated Forces (CGF) system for creating and controlling entities on a simulated battlefield.

ModSAF simulated entities can behave autonomously; they can move, shoot, communicate, and react, without operator intervention. These entities can interact with each other and with manned simulators on the network" (Loral, 1993, p.1).

This system can be used to support virtual simulations like the Close Combat Tactical Trainer (CCTT) by acting as the opposing force or as an adjacent unit. (CCTT actually uses a CGF called CCTT SAF, that is much like ModSAF.) ModSAF can also be used as a simulation to drive a higher-level staff command post exercise.

In the article, *Testing Future Weapons Systems Using CGF Systems*, Craft and Karr explain the use of CGF as an acquisition analysis tool. "The evaluation of a weapon system (or a simple vehicle or tactic) using the techniques described requires a suitable CGF system along with the people who know how to use it and software engineers capable of enhancing it. Experts are required to develop test scenarios and evaluation metrics for the experiments. Project members are needed to examine the statistical significance of the experiments" (Craft and Karr, 1996, p.13).

Craft and Karr used ModSAF to experiment with the Advanced Amphibious Assault Vehicle (AAAV). Using two scenarios, they modeled the difference between two variants of the vehicle—one with a Javelin Anti-Tank missile, and one without the missile. They conducted eighty runs of each scenario. The most interesting thing about this study was the potential problems cited with the ModSAF version 2.0 as a potential test for weapons systems. Some of the problems were: "*Javelin targeting*: On those occasions that a AAAV fires a second Javelin while one is in flight, the second always uses the same target as the first [missile fired] (this is very unrealistic). *Locked Target Priorities*: a Javelin equipped

AAAV should not seek tanks to kill but it should defend itself. As ModSAF stands, tanks are targets (on the priority list) or not (off the priority list)" (Craft and Karr, 1996, p.14).

Their conclusion was " CGF systems can be used for evaluating future systems but it is a complex process. A CGF must be altered to support the system to be tested, a variety of appropriate scenarios must be developed and implemented, MOE's are needed for the scenarios and should be instantiated in software, and enough experimental runs are needed to determine statistically significant results" (Craft and Karr, 1996, p.15).

This paper is a good guide for how to set up a comparison test in one weapon system, as it shows some of the difficulties in developing the necessary behaviors to model a new weapon system. It is a good starting point to understanding the subtleties of ModSAF.

2.3 Doctrinal Development using Simulations

Just as simulation can be used in developing new weapons systems, it can serve as a tool to evaluate doctrine. The 1996 Defense Science Board (DSB) Summer Study Task Force on Tactics and Technology for 21st Century Military Superiority studied a new military concept using simulation. The simulation efforts were in support of the current Army digitization efforts of Force XXI and the Army After Next (AAN). The central focus of the Summer Study Task Force was studying the effectiveness of using lighter, yet more heavily armed units than are currently available, equipped with non line of sight weapons and sensors to defeat a numerically superior armor heavy force. The Small Team Concept 21 (STP21) is an idea to employ units comprised of large numbers of specially trained and equipped teams consisting of 4 to 12 soldiers of soldiers with sensors and C^2 capability to control a large

geographical area using precision guided munitions (Coe, Madden, Mengel, and Wright, (1997), p.I-1).

Several separate studies were made on this broad concept of smaller, lighter, but more lethal forces. DSB task force engaged RAND Corporation to use constructive simulation to study this concept in terms of the capabilities of a theoretical Division Ready Brigade (DRB), like currently found in the 82nd Airborne Division. The DSB task force also conducted a virtual simulation experiment to further develop the tactics and doctrine of the STP21 teams, using human-in-the-loop concept. These two experiments are discussed in greater detail (Matsumura, et al., 1997, p.2).

2.3.1 RAND: Analytic Support to the Defense Science Board

As mentioned above, the RAND study used constructive simulation to develop the employment of a smaller more lethal unit than is currently being used in the Army today. This unit would have enhanced Command, Control, Communication, and Information (C4I) capabilities and be more lethal, but would also be more strategically mobile (Matsumura, et al, 1997, p.2).

The primary objective of the study was to use a high-resolution simulation to explore and quantify the potential contributions of light force concepts in a specific set of circumstance—the early entry phase of a major contingency, when only light forces are in place. These light forces are required to defend a high-value area (airfield) against a large attacking armored force.

According to the study, " The small dispersed force concept can be quite revolutionary in form, with many implications for the conduct of future warfare. Use of

small dispersed forces may change this [the conduct of war] by minimizing the presence and vulnerability of U.S. troops, and by enabling small forces to take on the missions of much larger units. These forces will rely on non-line of sight systems to destroy much of the enemy force and avoid the high-attrition line of sight battle" (Matsumura, et al., 1997,p.4-7).

The RAND study attempts to answer four questions:

- What kind of opportunities do different Reconnaissance, Surveillance, and Target Acquisition (RSTA) concepts provide?
- How do different levels of target acquisition effect long-range weapons performance?
- Given best RSTA, can external long-range weapons defeat armor attack, or will units need organic capability?
- How does dispersion [of the units] affect the indirect and direct fire engagement dynamics?

These questions are based on new technologies and how to best use this technology in an operational scenario. The questions include new doctrinal uses of units equipped with improved capability. The RSTA systems, mentioned above, represent the use of technology to make a smaller force more lethal. They provide a unit with varying degrees of target acquisition, depending on the sensors provided in the RSTA systems. RSTA systems provide the test case Blue force with a means to increase the knowledge of the enemy disposition at greater ranges, with better levels of detection than is possible with the systems in a current DRB (Matsumura, et al., 1997,p.45-46).

To test the base DRB against the test DRB, Matsumura and others used an existing scenario developed by TRAC, U.S. Army Training And Doctrine Command Analysis Center, High Resolution Scenario 33.7. In this scenario, a partially attrited Blue DRB (following forced entry) faces a substantially larger Red force, a division (-) attacking along three primary avenues of approach. The Red force has some sophisticated weapons and little RSTA capability. The Blue force objective is to hold a key strategic point (an airstrip), until heavy reinforcements, now en route, can arrive. The Red objective is to destroy the Blue force as fast as possible before the reinforcements can engage. In the test case, the Blue force uses non line-of-sight weapons and the RSTA systems to engage the Red force at much greater distances and is more dispersed than the base DRB to protect itself from Red artillery.

The RAND study concluded that the base DRB, not augmented with RSTA and advanced weapons, would be overrun by the Red force. As the base DRB is augmented with different levels of RSTA and weapons, its ability to kill larger numbers of Red forces before the direct fire battle increases. It also shows that the dispersion of the base DRB with an improved RSTA/weapons mix allowed for better Blue force survivability. This was not true, however, when the Red force closed within direct fire range. The increased dispersion seemed to adversely affect the Blue's ability to mass direct fire systems when the battle developed into a close fight. Dispersion is a tactical choice and hence whether to disperse or not becomes a matter of tactical doctrine. Using the JANUS constructive simulation to address the employment questions above, the RAND study provides an example of how constructive simulation can be used to model new tactical doctrine based on emerging technology at a large unit level.

2.3.2 Defense Science Institute: Virtual Simulation Analysis

The Defense Science Institute took the large unit employment doctrine developed in the Rand study and tasked the Defense Science Institute to develop the small unit tactics for the teams using virtual simulation. Virtual simulation is characterized by a level of immersion of a player in the synthetic world (Proctor, 1997, class notes). In this study, human players were used to perform missions or tasks as members of the STP21 teams, mentioned earlier. They used future equipment and sensors, along with weapons modeled in the simulation. They interacted with ModSAF opposing forces and operated in the ModSAF synthetic environment.

The virtual exercises were designed to investigate variations in team size and composition, mission, organic sensor capabilities, and remote sensor suites. The simulation was developed on two different terrain databases, and seven record trials were accomplished. The number of trials was limited by time, equipment, and funding. The authors admit that there were insignificant trials to provide sufficient statistical power for analytical conclusions to be made. One interesting thing about these combined studies is the use of simulation to develop doctrine on a larger level using, constructive simulation, and then develop the tactics for these small units, using virtual simulation (Coe, Madden, Mengel, and Wright, 1996, p.I-1).

2.3.3 CASTFOREM

Combined Arms and Support Task Force Evaluation Model (CASTFOREM) is another model used by the Army to test effects of weapons systems against new threats.

It is a model used at the White Sands Missile Range (WSMR) TRADOC Analysis Center (TRAC). This model is very high resolution and is costly to use. According to Mackey, et al (1994), it is "a high-resolution, two-sided, force-on-force, stochastic, event sequenced, systemic simulation model of a combined arms conflict" (Mackey, et al., 1994, p.ix).

CASTFOREM was developed at TRAC-WSMR and " is the highest resolution and lowest hierarchical model in the Army's Model Improvement Program. It is a superior model for representing tactics through the use of decision tables and embeds an expert system for battlefield control. It is written in SIMSCRIPT II.5" (Mackey, et al., 1994, p.ix).

This model represents a high cost, non-exportable computer simulation for classified experimentation. Its use in the widespread commercial systems analysis is limited because of its governmental proprietary nature (Mackey, et al., 1994, p.ix).

2.3.4 Mounted Maneuver Battlespace Lab's 1998 Study of Battalion C2

Another study, made in June 1998, was a digital battle command experiment at the Mounted Maneuver Battlespace Lab, one of the U.S. Army's centers of learning in Doctrine, Training, Leadership, Organizations, Material, and Soldiers. The Mounted Battle Lab in conjunction with Army Research Institute conducted an experiment to understand the effects of digitizing C4I in a future maneuver battalion command group. Specifically, the objectives were " To obtain insights into the effects of improved Battlefield Visualization on Battle Command…To evaluate the implications of near-perfect situational awareness on doctrine, training, leadership, organization, material, and soldiers (DTLOMS)…. To develop a more effective Tactical Operations Center (TOC) through reengineering…To provide the intellectual underpinning for follow-on experimentation" (Ray, 1998, p.2).

This experiment used soldier-in-the-loop simulators and ModSAF computer generated forces (CGF) to evaluate the effectiveness of a task force TOC equipped with a future battle commander's display. ModSAF displays were used to simulate the battle command display in a number of reconfigurable simulators and the task force command group fought a series of battles using these tools. Army Research Lab (ARL), Army Research Institute (ARI), and the Test and Evaluation Coordination Office (TECO) collected data on the command group's command of the task force and their use of the displays.

The experiment included the staff and the commander of a task force and key sub unit commanders, like the scout platoon leader and maneuver company commanders. The human-in-the-loop simulators were reconfigurable simulators focusing on the battle command process, not vehicle fidelity. The battalion was a future combined arms battalion structure with three maneuver companies each with 14-15 battle systems, either armor or infantry units. The scenarios were run on Germany and National Training Center (NTC) databases and replicated typical military operations (Ray, 1998, p.16).

The use of a combination of human-in-the-loop simulators and CGF to study battle command provides a look at how the real staff might operate to command and control a military force in a future battle setting. The subjects in this particular experiment were actual maneuver battalion staff officers from an existing unit in FT Hood, Texas. The players were actually serving in the positions played in the experiment. This lends some validity to the results. However, like the previous study, the number of trials conducted in this experiment were limited by fiscal and other constraints and the data collected was insufficient to make real statistical conclusions (Ray, 1998, p.19).

2.4 Using Constructive Simulation to Develop Small Unit Tactics

In a study made at the Naval Postgraduate School in 1994, Sobey demonstrated the creation of a new vehicle type, the Advanced Amphibious Assault Vehicle (AAAV) using ModSAF. He also created a unit and associated behaviors that would allow this amphibious vehicle to traverse the sea paradigm to the land using a land type vehicle. Sobey demonstrated the creation of embark and disembarking behaviors using the AAAV moving on and off a landing ship. In his conclusion, he calls on the need to simulate the tactics and organizational structure of the advanced AAAV for the U.S. Marine Corps (Sobey, 1995, p.44).

In a similar study, Lartigue and others developed several variants of the Future Scout Vehicle (FSV), while creating a basic scout/reconnaissance behavior for analysis of this system, called Tracer Recon. Lartigue used these basic entity changes to model a new measure of reconnaissance effectiveness—Intent. This study used five scenarios to test five different variants of the FSV. Lartigue conducted 10 runs per vehicle per scenario for a total of 200 runs. For this test, the Tracer Recon behavior was used to model the scouts as they encountered enemy vehicles. The Tracer Recon behavior allows the FSV variants to call for indirect fire on enemy that the scout identifies, seek cover when the scout is fired upon, and conduct tactical movement using the terrain.

Although the study changed the basic entity behavior, the behavior across variants did not deviate. All variant tactical movement were the same for the tasks in each of the five scenarios. For example, the tactical movements for a highly armored vehicle were the same as those of a lightly armored vehicle. The tasks were selected to achieve the reconnaissance

objectives that would best measure the collection of intent. In his conclusion, he suggests that the "idea of changing of the behavior of scouts based on the vehicle capabilities would provide interesting insight as to the effective employment of the proposed system" (Lartigue, 1998, p.111).

2.5 Using Constructive and Virtual Simulation to Develop Small Unit Tactics

Another recent tactics study using both constructive and virtual simulation was one conducted by Platoon/Company/Team (PLT/CO/TM) Tactics Branch at the DTDD in April 1998. In an Armor magazine article, *Exploiting Precision Maneuver: An Experiment to Evaluate M1A2 Tactics, Techniques, and Procedures,* members of the PLT/CO/TM branch of DTDD, explain a series of experiments evaluating small unit M1A2 tactics.

As background, the M1A2 is an upgraded main battle tank that adds improvements in fire control, communications, and situational awareness. The tank is already fielded to units at FT Hood, TX and is in full production. The interesting concept behind the DTDD experiments is the possibility for the creation of different tank platoon tactics based on enhanced capabilities of the weapon system. The equally interesting aspect about these tests is that the tests are being conducted by DTDD, which develops and approves current tactics for the U.S. Army Armor force. Consequently, at least one experiment to develop tactics is being conducted after the system has been shipped to a large number of units. One report states, "The 1st Cavalry Division at Fort Hood, the first U.S. Army unit equipped with the M1A2 identified critical doctrinal shortcomings of TTPs available for this tank. These units cannot take full advantage of the enhanced capabilities of the new platform using the old TTPs" (HQDA, 1998 (September-October) (a), p.44).

The DTDD experiment had two phases: constructive and virtual. In the constructive experiment a total of 47 runs were conducted using the Battlefield Environment Weapons System Simulation (BEWSS) model in the Interactive Distributed Engineering Evaluation and Analysis Simulation (IDEEAS) environment. The test used two terrain databases, and different vehicle dispersions and defilade positions to evaluate current TTPs and new TTPs.

The virtual experiment used four Close Combat Tactical Trainers (CCTT) to test the findings of the constructive simulations in a limited number of runs on one database. The experiment seemed to show some subtle and drastic changes for TTP needed based on the introduction of the M1A2 and its increased capabilities (HQDA, 1998 (September-October) (a), p.44).

2.6 Gap in the Literature

In this chapter, the research shows examples of constructive and virtual simulation used to develop new weapons systems, simulations used to test large unit tactics and new organizations, and a mix of constructive and virtual simulation used to develop tactics in small units. In particular, this chapter shows how ModSAF, as a constructive simulation, is widely used and accepted for concept exploration. What is not present in the literature is any evidence of revising small unit tactics, techniques and procedures concurrent with the development the material aspect of a new weapon system. Specifically, while six categories of requirements are possible-- doctrine, training, leadership development, organization, materials, soldier systems (DTLOMS) (TRADOC, Pam 71-9)--once a material need has been identified it is not clear that the other five categories of potential change are revised along with the material system during its analysis in a constructive simulation.

What if tactics or doctrine for small tactical units could be developed or tested using constructive simulation in conjunction with the concept exploration phase of the acquisition process of new material? By developing tactics, or organizational behaviors, during the first phase of the acquisition process, the product package would include the weapon system and a recommended behavior (e.g. TTPs) to optimize the advances incorporated into the system. What is of interest in the research is the tactics for a unit level scout vehicle. In the next chapter, the research will explore current scout platoon organization and tactics to develop a better understanding of tactical behaviors. To do this, the next chapter will answer the following questions:

- What are the types of unit tactics that need to be considered in this research?
- How might differences in systems design effect the choice of the tactics employed?

CHAPTER 3

GROUND RECONNAISSANCE BEHAVIORS IN THE US ARMY

3.1 Aggressive Reconnaissance vs. Stealth Reconnaissance

For small unit scout reconnaissance, one tactical doctrine question that is currently being debated in US and allied military circles is how ground scout units should conduct reconnaissance missions?

Scouts have a dangerous job. The debate comes with how they should perform this job. One school of thought is the aggressive one. A scout should seek out contact with forces in its area of operations and then use direct and indirect fires to engage the enemy. This helps develop the situation, it allows the scout to gain contact, and to provide the higher headquarters with combat information. The danger is in the enemy's capability to destroy the scout. Ideally, the scout could perform its mission, as stated above, while retaining freedom to maneuver, which includes the ability to stay alive and be effective.

Another method of performing these reconnaissance tasks is to use stealth. A stealthy scout would use the terrain, weather, and the time of day to his advantage. The type of transport a scout has also might benefit him—the bigger and louder a vehicle is the less stealthy, but also possibly offering less protection.

The US Army currently provides High Mobility Vehicles (HMWVV) to most of it's mechanized or motorized reconnaissance units. This is a quiet, mobile, yet less protected light vehicle—the military version of a four-wheel drive sport utility. The M3 Cavalry Fighting Vehicle, CFV, is a larger, noisier scout platform that is also in use for reconnaissance for some cavalry formations. It is a tracked vehicle that is armed for more aggressive behavior and is better protected. Neither vehicle, however, can stand up to a modern tank's weapons.

A new scout vehicle is currently under development that incorporates advanced sensors and weapons with protection that provides an improvement over the current scout vehicles. The same old question arises, however, that is, "how much stealth and how much aggressiveness?" This thesis intends to explore this question through constructive simulation. First, the research will examine the basis for existing reconnaissance behaviors and units in the U.S. Army.

3.2 Historical and Current Reconnaissance Behaviors

To get a historical perspective on ground reconnaissance, the researcher examined an excellent monograph on tactical reconnaissance written by Major James Diehl, an Armor officer, while a student of the School of Advanced Military Studies at Ft Leavenworth, Kansas. He studies the recent history of tactical reconnaissance by examining the German, Russian, and U.S. reconnaissance experiences of World War II, the last major U.S. ground war involving large numbers of mechanized units, prior to Desert Storm.

According to Diehl, the Russians proved to be a formidable foe for the Germans.

> Pre-war German doctrine envisioned the acquisition of combat information as the dominant mission for reconnaissance formations. Initially, the Germans employed their formations to accomplish just those missions. However, the war with the Russians turned out to be more vicious than the Germans anticipated.
>
> Reconnaissance efforts were to be contested at every turn. The Germans found themselves fighting for whatever information was gleaned from reconnaissance. The Germans stealth tactics overlooked bypassed Soviet strong points which caused extensive problems for following forces. (Diehl, 1988, p.11)

As the war progressed, the Germans were forced by circumstance to form ad hoc formations of tanks, infantry and other systems to fight for tactical intelligence. In Diehl's words, "reconnaissance had became everybody's business" (Diehl, 1988, p.35).

The Russians had been more visionary in their pre-war doctrine. According to Diehl, " the Soviets envisioned that tactical reconnaissance would be an all arms affair and their organizations reflected this." During the war, the Soviet doctrine altered little as they found that their pre-war tactical theory worked in practice. They used a combination of stealth and combat reconnaissance to perform their missions. " The Soviets were capable of performing the stealth reconnaissance with dismounted infiltrators and could perform combat reconnaissance in up to reinforced motorized rifle regiment strength" (Diehl, 1988, p.13).

The American experience in World War II was similar to the German one. The pre-war doctrine recognized stealth as "the appropriate means of obtaining intelligence." But during the war, the Americans found that "the typical reconnaissance mission was punctuated by surprise combat and the scout had to be prepared to win that fight." The main theme of Diehl's work is that future tactical reconnaissance will require a combination of stealth and combat reconnaissance tactics and that American scout and

cavalry formations were not equipped to perform their missions without the support of maneuver battalions and other assets. He concludes, "it's [tactical reconnaissance is] not just up to the scouts" (Diehl, 1988, p.36).

Diehl wrote this monograph at a time when the U.S. Army faced the threat of conventional war in Europe and before Operation Desert Storm, the short war against Iraq in 1990; but, his work continues to provide an interesting historical overview of tactical reconnaissance.

3.3 Rand Corporation Study on Battalion Scouts at the National Training Center

Another study conducted by the Rand Corporation in 1987, with a follow up in 1994, concerned U.S. Army reconnaissance at the battalion level. This study was conducted at the National Training Center, a live simulation center located in California. The researchers studied the results of 63 offensive missions involving 14 different battalions and tactical reconnaissance. The researchers found that battalion scout platoons were inadequately equipped to conduct stealth reconnaissance. The platoons were, at the time of the first study; equipped with a mix of Bradley's and M113 series tracked combat systems. The study recommends the incorporation of a stealthier wheeled vehicle. By the 1994 follow up, most platoons were fully equipped with ten HMMVW's and had no tracked vehicles.

Interestingly, the 1987 Rand study recommended, "A small number, perhaps two, wheeled vehicles should be added to the scout platoon for the purpose of adding stealth and numbers." The U.S. Army, instead, replaced all of the Bradley's and M113's with HMMVW's and added four systems for a total of ten scout vehicles per platoon. The

Rand study also recommended an added emphasis on the use of more than just the scout platoon in a mechanized battalion for reconnaissance. Since these early studies, changes have been made in the U.S. Army's tactical reconnaissance formations. Tanks were put back into division cavalry squadron and HMMVW's were introduced to the scout platoons of the mechanized battalions (Goldsmith and Hodges, 1987, p.67).

In a similar monograph discussing the necessity of creating a brigade reconnaissance troop, Lieutenant Colonel (LTC) McCarthy discusses the HMMVW scout platoons abilities, "Because of the HMMVW's vulnerability, the [battalion] scout platoon must conduct stealthy reconnaissance. In order to use a combination of stealth and aggressive reconnaissance techniques, the task force [a battalion with both tanks and infantry] must either provide the scout platoon with additional maneuver BOS [battlefield operating systems] assets or give control of the platoon to a larger reconnaissance force [like a division cavalry squadron]" (McCarthy, 1994, p.12).

3.4 Examination of the Current US Reconnaissance Doctrine

To understand more about the role of scouts, the use of reconnaissance in US doctrine needs to be more closed examined. FM 100-5 is the overall operational manual that defines basic military concepts for the Army. FM 17-95 concentrates on Reconnaissance operations. FM 17-12 and 98 concentrate on small unit reconnaissance activities.

FM 100-5, Operations, the overall Army warfighting doctrine, discusses Commander's offensive planning role,

> Commander's get directly involved in deciding priorities for reconnaissance and intelligence operations. Commanders aggressively seek gaps or weaknesses in the enemy's defenses; study enemy defensive preparations and attempt to obstruct and frustrate those preparations; and plan to penetrate enemy security areas, overcome obstacles, avoid the strengths of established defenses, and destroy the coherence of the defense. All of this requires an active, predictive intelligence effort oriented on critical units and areas.
>
> In a force-projection army, where forces are often offset a great distance from their full complement of support, tactical units frequently turn to senior headquarters for answers to tactical intelligence requirements before they can do their own intelligence-gathering activities. These include identifying and locating enemy reserves as accurately as possible; locating and tracking enemy fire support systems; gathering information about enemy intelligence capabilities, to include air capabilities and air defenses. *Aggressive reconnaissance* [emphasis added] to see the enemy and to anticipate his reactions, coupled with equally aggressive force-projection actions, is also important to getting and keeping the initiative. (HQDA (b), 1995, p.145)

This gives you an understanding of how the commander uses reconnaissance and how important reconnaissance is to the overall scheme of maneuver.

FM 17-95, *Cavalry Operations*, provides a good discussion on the differences between aggressive and passive reconnaissance methods.

> Reconnaissance involves two contrasting methods. First is reconnaissance by stealth. Using this method, cavalry avoids physical contact with the enemy and gathers information by quiet, deliberate, dismounted techniques. Surveillance is the primary task performed. The second method is aggressive reconnaissance and fighting for information as necessary. Using this method, cavalry avoids decisive engagement, but prepares to fight, especially enemy security and reconnaissance forces, to gain information. This method does not have to be as stealthy and may proceed at a faster pace.
>
> Historically, the best way for cavalry to obtain information on the enemy has been aggressive action requiring combat; in other words, fighting for information. Fighting for information means employing reconnaissance by fire, attacking the enemy with fire, and conducting hasty attacks with subordinate units. Fighting for information does not entail units as a whole becoming decisively engaged,

> conducting deliberate attacks, or assaulting a prepared position. Through fighting for information, cavalry forces the enemy to disclose not only his disposition but also to reveal his intent and will to fight. (HQDA (a), 1996, p.3-2)

Certain fundamentals of reconnaissance are further explained in the Cavalry Operations manual, FM 17-95,

> - Use maximum reconnaissance forward
> - Orient on the reconnaissance objective
> - Report all information rapidly and accurately
> - Retain freedom of maneuver
> - Gain and maintain contact
> - Develop the situation rapidly. (HQDA (a), 1996, p.3-3)

These reconnaissance fundamentals seem clear, but there is some gray area here. Retaining freedom of maneuver means not becoming pinned down by enemy actions, usually direct or indirect fire. The next principle is tricky to accomplish given the previous one. To gain contact is sometimes simple; the trick is in maintaining contact without getting destroyed. From FM 17-15, *Tank Platoon*, contact can be further defined as seven common types of situations; there may be more:

> - Visual contact
> - Physical contact
> - Indirect fire contact
> - Direct fire contact
> - Electronic warfare contact
> - Chemical or nuclear contact
> - Obstacle contact [land mines, for example]. (HQDA (b), 1996, p.3-21)

You can see how some forms of contact to a scout would be more desirable than others in accomplishing their mission (not to mention staying alive) and how dangerous others could be.

FM 17-98, *Scout Platoon,* the manual for the lowest level of scout organization in the Army, defines reconnaissance as a means "...to provide current and accurate information about the terrain, resources, and enemy within a specified area of operations. This provides follow on forces with an opportunity to maneuver freely and rapidly to their objective" (HQDA, 1994, p.3-1).

3.5 The Current Mechanized Battalion Scout Platoon

To better understand the way the U.S. Army uses reconnaissance assets, a better understanding of the organization of fighting units is necessary. The U.S. Army is organized into a hierarchical structure composed of units. The battalion is the lowest unit that has a functional staff to assist the commander in combat operations. In the U.S. Army, this organization is backbone of tactical operations. A battalion is composed of a number of companies, which are composed of a number of platoons. A tank battalion, for example, has five companies, four tank companies and one headquarters company. The tank companies are the maneuver elements that the battalion commander can command and control to accomplish his mission. The scout platoon is the eyes and ears of the maneuver battalion commander. According to FM 17-98, the scout platoon "provides the information necessary to allow combined arms forces to maneuver against the enemy, strike him where he is most vulnerable, and apply overwhelming power to defeat him" (HQDA, 1994, p.1-1).

Mechanized infantry or tank battalions have one scout platoon equipped with six or ten scout vehicles and up to thirty scouts. A Lieutenant and a Sergeant First Class lead the platoon. Currently, there are two kinds of scout platoons in service with the Army's

mechanized forces-- HMMVW or Bradley-equipped platoons. The platoons are basically the same, and operate under the same tactical doctrine outlined in FM 17-98, *Scout Platoon*. However, most Bradley equipped platoons are found in armored cavalry organizations, which are organized and equipped differently than mechanized battalions and have missions similar to the battalion scout platoon, only operating for a much higher commander. The HMMVW equipped platoon is the primary mechanized battalion scout platoon vehicle.

LTC McCarthy (1994) includes a good synopsis of the scout platoon,

> As currently equipped this ten vehicle 28-man platoon has a mix of 40-millimeter automatic grenade launchers and machine guns for self-defense. It has a passive night vision devices for use during periods of limited visibility, and conventional radios for reporting information. The platoon leader tailors his platoon based on how much time he has to accomplish the mission, how many tasks the battalion has assigns him, and how much space he has to reconnoiter. When the platoon leader has enough time he may dismount all or part of his platoon to infiltrate the enemy security zone...If the platoon leader must remain mounted, he may deploy five two-vehicle squads, two five vehicle sections, or any combination between these two extremes. (McCarthy, 1994, p.11)

3.6 Battalion Scout Platoon Tactics -- Actions on Contact

In order to develop a difference between passive and aggressive behaviors, this research focused on the primary difference between the two tactics. The difference between this research representation of the two tactics is simple. This research simply modifies the weapons control status of the vehicle entities. In the next chapter, the research discusses the particular tactics representation in the ModSAF model.

A better understanding of the real tactical differences, however, is required to fully appreciate the characteristics of the two tactics. A passive scout seeks to avoid direct enemy contact, in all forms. He seeks to obtain visual, audio, or other type of

sensory contact, without the enemy being aware of his presence. An aggressive scout seeks the same, but acts on contact with the enemy to engage and destroy him.

Historically, aggressive or combat reconnaissance used a variety of means to seek contact, like reconnaissance by fire and reconnaissance by demonstration. Reconnaissance by fire is simply firing at suspected enemy locations attempting to provoke the enemy into giving away his positions by returning fire. Reconnaissance by demonstration is finding the enemy by letting him see you and waiting for him to open fire on your unit, there by giving away his position.

The U.S. Army provides the scout with guidance on how to react to contact in FM 17-98. The five guidelines to actions on contact are:

- Remain focused on the reconnaissance objective
- Report quickly and accurately
- Maintain contact with the enemy
- Retain freedom to maneuver
- Develop the situation rapidly. (HQDA, 1994, p.3-44)

The manual also provides four steps for actions on contact: deploy and report, develop the situation, choose a course of action, and recommend and execute a course of action. When initial contact is made it can take one of four forms to the scout.

- Physical contact with a superior or unknown enemy
- Physical contact with an inferior enemy
- Contact with aircraft
- Contact with indirect fire

When initially making visual contact with any of these forms of contact, the scout performs the first step of actions on contact--deploy and report. The scout deploys to

covered and concealed terrain to provide some protection from the enemy weapons or sensors. The scout returns fire, if fired upon, or remains concealed if not noticed by the enemy. The scout then reports initial contact to higher headquarters in a quick manner, just to let the leader know it is in contact. The scout sends a more accurate report after it has developed a clearer picture of the situation, or after it is in a safer position (HQDA, 1994, 3-44, p.3-46).

This reporting leads to the next step in the actions on contact--develop the situation. The scout may or may not have a full picture of what he faces after initial contact with the enemy. He may be fighting for his life or may be pinned down by fires. The scout must now decide how best to obtain additional information about the enemy force. Current doctrine suggests a combination of mounted and dismounted reconnaissance and reconnaissance by fire to further refine the information about the enemy force. The scout platoon leader can decide to augment the unit in contact to further define the enemy force or to find the flanks of the enemy.

This process is in preparation to choosing a course of action for the platoon or the unit in contact. This is the next step of the action on contact drill. The scout in contact and the scout platoon leader have several options at this point, depending on the situation. The platoon leader may choose to break contact and bypass the enemy force. He can maintain contact and attempt to bypass the enemy. If he can not destroy the enemy with his available assets, he can maintain contact and prepare to assist or support a hasty attack by elements of the maneuver battalion. If he can destroy the enemy force with his platoon and the reconnaissance mission will benefit or not be compromised, he can

conduct a hasty attack with the platoon. He may decide to put the platoon in a hasty defense, if the enemy cannot be bypassed or all teams are fixed by the enemy force.

After deciding on a course of action, the platoon leader performs the last step in the actions on contact drill--recommend and execute a course of action. The battalion commander or staff makes the decision and orders the scout platoon leader to execute a course of action. If there is no contact with higher headquarters, the scout platoon leader decides independent of the higher headquarters, based on the commander's intent given in the operations order (HQDA, 1994, p.3-46).

The actions on contact drill is a continuous process that occurs on each contact with the enemy. Because of the limitations of the current HMMVW scout vehicle, many of these courses of action are limited.

According to FM 17-95, the HMMVW scout has the ability to suppress light armor and can destroy infantry and light unarmored vehicles. It can not destroy light armored vehicles, but can be destroyed by most weapons greater than individual small arms. This puts the HMMVW at a particular disadvantage. It can, therefore, only conduct four of the five course of action with varying degrees of difficulty. It can not perform the hasty attack in many situations where the enemy is more than lightly equipped. It also may have trouble maintaining direct fire contact with many enemy weapons systems without risk of being destroyed. The HMMVW is therefore reliant on gaining stealthy contact with the enemy. It is a quiet vehicle that is able to move well across country in most environments, but it also is not as capable as tracked vehicle in

cross-country movement, especially at night. It can move very well on paved or road surfaces, however (HQDA, 1994, pp.1-5, 1-6).

3.7 Research Questions

The basic idea behind this research is the question, "Is there a difference in tactical outcome due to the use of aggressive or passive land-based reconnaissance by different reconnaissance vehicle systems and can tactics and vehicle systems be developed concurrently?" This thesis explores that point with the following questions,

- Is there interaction between vehicle-type and tactical behavior in the tactical outcome of battalion-level land based reconnaissance?
- Is there a difference in the tactical outcome based on tactical in battalion-level land-based reconnaissance?
- Is there a difference in the tactical outcome based on variant-type in battalion-level land-based reconnaissance?

This research explores these questions using two different tactical behaviors and two different land-based reconnaissance vehicles in a constructive simulation experiment. Research asset limitations require the use of ModSAF and its methods to represent tactical behavior and reconnaissance variants. These include an acquisition methodology based on Night Vision Laboratories' algorithms, ModSAF finite state machines (FSM) to represent various tactical behaviors and research methodologies, and classified systems data provided by Lockheed Martin and various government sources. Research assets limitations further confined the study to one environmental setting-- moderate weather. Passive and aggressive behaviors will be represented as a modifications of an existing

ModSAF finite state machine (FSM) reconnaissance behavior, "Tracer Recon." The research does not intend to replace the FSM approach to representing tactical behavior. The modifications of the tactics will focus on the scouts' passive or aggressive reaction to contact with an enemy force. Representing vehicle differences will be accomplished by changing data and algorithms within the FSM.

CHAPTER 4

RESEARCH METHODOLOGY AND THE DEVELOPMENT AND EVALUATION OF EFFECTIVE RECONNAISSANCE TACTICS IN MODSAF

4.1 Introduction

Using the two scout vehicle variants and the two tactical behaviors discussed in the previous chapter, this research explores the effectiveness of developing and evaluating new weapon systems concurrent with the development of new tactical behaviors during the concept exploration phase of the weapon systems life cycle. Prior to conducting the experiment over 50 hours were invested developing the scenario. Scenarios for each course of action by variant were tested. This test allowed for the refinement of the scenario and the identification of areas that could be improved. This chapter addresses the research methodology used to explore these representations. First, the chapter discusses the experimental design. The next section of the chapter discusses the key differences between the representation of aggressive and passive reconnaissance behaviors and how they will be implemented in ModSAF. Thirdly, since the Future Scout Vehicle (FSV) variants are different in terms of protection, firepower, and sensors, the chapter addresses representing these two different FSV variants in detail. The next section addresses the selection of the scenario used to test the behaviors.

This scenario is modified to provide some measurement space for the measures of effectiveness. Finally, the last section addresses the measures of effectiveness (MOE) for evaluating the behaviors and vehicle configurations. A stochastic model--ModSAF version 3.0 Custom (Lockheed Martin Electronics and Missiles)--provided the means to conduct simulation runs that address scout platoon effectiveness with different vehicle capabilities, using different tactics.

4.2 Experimental Design

The research experiment consisted of 40 runs for each variant for a total of 80 simulation runs. This is a classic 2 x 2 factorial experiment. The experiment has two factors - vehicle type and tactic. There are four treatments, which are the combinations of the four factors. There were twenty replications of each treatment. Table 4.1 shows the experimental design.

Table 4.1. Experimental Design Table

Factors	Stealth Variant	Protect Variant	
Aggressive Behavior	20 Replications	20 Replications	40 Total
Passive Behavior	20 Replications	20 Replications	40 Total
	40 Total	40 Total	80 Total Replications

4.3 Behavior of Real Entities in ModSAF

To represent aggressive and passive tactical behaviors, the research will use existing ModSAF constructive simulation features. In order to develop a computer simulation of a behavior, it is important to understand how the specific system models

behave currently as well as what aspects might need to be modified to represent the new behavior under consideration.

4.3.1 Finite State Machines

In ModSAF, behavioral tasks have been implemented using asynchronous augmented finite state machines (AAFSM). They are called augmented FSM's because they can influence and use many variables other than their state variables. They are asynchronous because they generate outputs in response to events in the simulation (Loral, 1993, p.39). The FSM in ModSAF is a modified state transition table that allows for easier interpretation and debugging. A preprocessor utility reads the AAFSM format and translates it into C code.

4.3.2 Tasks

"The automated behavior performed by a ModSAF entity or unit is governed by *tasks.* Examples of tasks include behavior such as move, orbit, avoid collisions, and search for enemy vehicles. These tasks are typically implemented as augmented finite state machines" (Loral, 1993, p.37).

To model reconnaissance tasks, "ModSAF uses a set of representative tasks for both individual (vehicle) or collective (unit) tasks" (Loral, 1993, p.37). These entity tasks could include a vehicle occupying a position or a company attacking an objective.

4.3.3 Task Frames

ModSAF uses task frames to group related tasks together allowing the tasks to run concurrently. A task frame is used to allow the entity to conduct a mission that includes many different functions. A unit moving along a route could use a move task, a collision task, and a fire task to engage a spotted enemy. A task frame may also allow an entity to stop running that frame for a while and run another task frame conducting another group of related tasks until some event returns the entity to the original task (Loral, 1993, p.36).

In ModSAF, tasks can be linked together in task frames to conduct certain actions, or missions. The mission, like assault an objective or conduct reconnaissance, is a collection of one or more task frames (Loral, 1993, p.37). This CGF system allows a single operator to assign missions to many entities and control their actions. This is possible because the unit and individual entities can act and react according to preset behaviors in the tasks.

4.3.4 Behavior Modification of ModSAF Reconnaissance Entities

In his work with the introduction of the reconnaissance metric, intent, Lartigue (1998) developed a reconnaissance behavior called "Tracer Recon." Lartigue's "Tracer Recon" incorporates tactical movement, reporting, observation methods, sensor control, reaction to contact and rules of engagement, call for indirect fire, C4I, and observation post activities into the Tracer Recon behavior (Lartigue, 1998, pp.40-43).

While assigned the Tracer Recon task, a scout vehicle or unit, moves along a specified route or towards a particular objective. As the scout moves the sensors on

board search according to a predefined pattern for enemy entities. On a specified interval, the vehicle or unit stops and conducts a sensor search. The sensors are elevated to the height of 6-15 meters on a raised mast. The sensors then sweeps on a specified arc. The scout detects targets based on a variety of factors, and attempts to identify all targets. It continues to search until all targets are identified or a specified time elapses. The scout then continues to move to the objective. Along the route, the scout can be engaged, if identified, and if it is engaged it will attempt to seek a hide position. The scout will return fire based on the weapons control status, specified by the user, and when hidden, remain so until a specified period of time elapses. As the scout senses targets, it reports all target locations and if a fire direction center unit is available it will call for indirect fire on all targets it senses (Lartigue, 1998, pp.40-44).

TRACER RECON SYNOPSIS

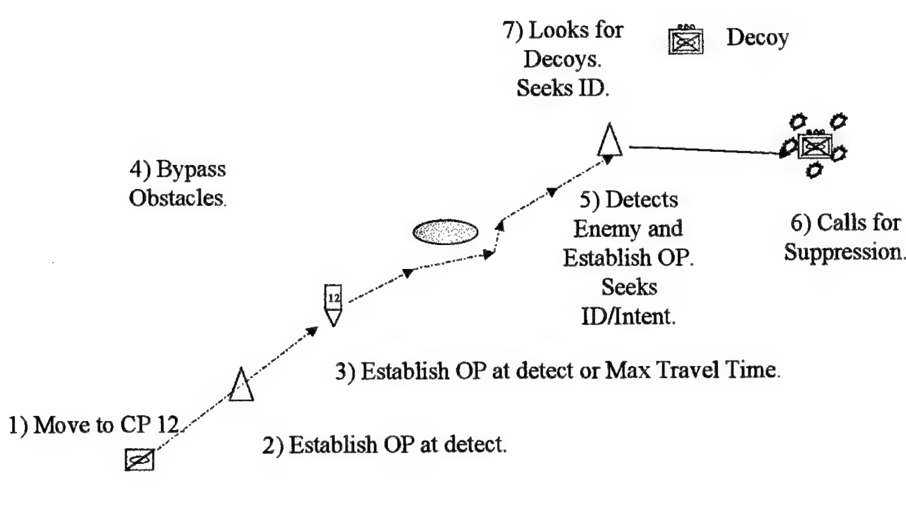

Figure 4.1. Tracer Recon Behavior in ModSAF

4.3.5 Issues with the Existing Tracer Recon behavior in ModSAF

There are several issues yet to be addressed by the Tracer Recon behavior. The Tracer Recon allows FSV variants with high signature control to avoid detection by the enemy, based on the sensors of the enemy and the proximity to the enemy vehicle. If an actual tracer unit fires its direct fire weapons, the vehicle might lose its signature control capability and temporarily become more "visible" to the enemy unit within a "line of sight" to the FSV. This reality is not currently modeled in the Tracer Recon.

The Tracer Recon will not necessarily react to the detection of a target, except to call for fire or use it's direct fire weapons, depending on other ModSAF behaviors. The FSV should react to enemy identification to perform one of the courses of action for actions on contact mentioned earlier. Bypass (passive tactic) and conduct a hasty attack (aggressive tactic) are the two actions on contact that are pursued in modifying this Tracer Recon Behavior.

4.4 Cooperative Behavior in Simulations

Another issue with the Tracer Recon behavior, indeed with ModSAF in general, is that units do not currently cooperate as a unit as they move to their objective. For example, ModSAF entities do not interact within units to share information on enemy contact, nor do smaller units interact with higher headquarters' commanders to affect the commander's decision making process. ModSAF also does not model the collective interaction of a unit in combat. For example, while radio messages and communication is modeled, the scout platoon, as a unit, does not act on such radio messages.

Further, if an entity is moving near a fellow vehicle and the fellow vehicle is engaged and subsequently destroyed, the entity will not aid the fellow vehicle as it accomplishes it's own task, because it doesn't recognize the fellow vehicle as requiring assistance. This is a flaw in ModSAF as is noted in the work done by Hoff and Lee (1998) on marine infantry task organization." In ModSAF, independent units essentially ignore each other when they act. For instance, two infantry squads tasked to march along the same route will overrun and intermingle, acknowledging each other only as obstacle" (Hoff and Lee, 1998, p.36).

In the real world, military units work together. Rajput and Karr (1996) discuss the cooperative behavior of military entities in the real world. On a real battlefield, soldiers and vehicles (actually soldiers inside the vehicles) cooperate in most situations. They may cooperate:

- by coordinating movement and fire,
- by understanding the unit's plan and their role within it,
- by reacting to the unexpected events in acceptable ways,
- by passing through information
- by following commander's directives.

A unit in the battlefield has a hierarchy of command which reflects the information flow from top to bottom levels (Rajput and Karr, 1996, p.189).

Within his thesis, Lartigue (1998) recognized this issue, as well.

> The scout behavior does not account for some aspects of scout unit interactions. These include reaction of a scout section to a single contact to develop the situation, entire unit route changes base (sic) on certain sections in contact, bounding within sections based on overwatch of other entities, and adjustment of

> sectors based on unit attrition. Some of these unit interactions could enhance the scout's ability to achieve intent by working together (especially in zone reconnaissance). (Lartigue, 1998, p.67)

There may be some bias between the recon vehicle types when considering cooperative behavior in ModSAF. The passive scout may need to cooperate more with its peers to accomplish its mission than the aggressive scout. If a scout sees an enemy unit in the path of another scout, the real scout would be able to warn its peers and perhaps change their behavior, as long as the peer had communication with the first scout. An aggressive scout might be able to simply destroy the target it encounters, depending on its choice of weapons and the weapons' effectiveness versus that target. This research assumes that the aggressive scout could benefit equally from information from its peers, in that it could use the peer's contact report to plan a hasty attack on the enemy, much like the passive scout might use the information to bypass the enemy and avoid contact. This may mitigate some of the perceived bias in the two vehicles. Scenarios incorporate cooperation into the scenario by manually varying the times and routes of the main body based on the reconnaissance results from the different variants.

4.5 FSV Battalion Scout Platoon Tactics -- Aggressive Actions on Contact

The aggressive behavior for the new FSV scout platoon will focus on the hasty attack action on contact drill. With a better-protected vehicle and a more effective gun, the aggressive scout might prove more able to destroy a wider range of enemy weapons systems.

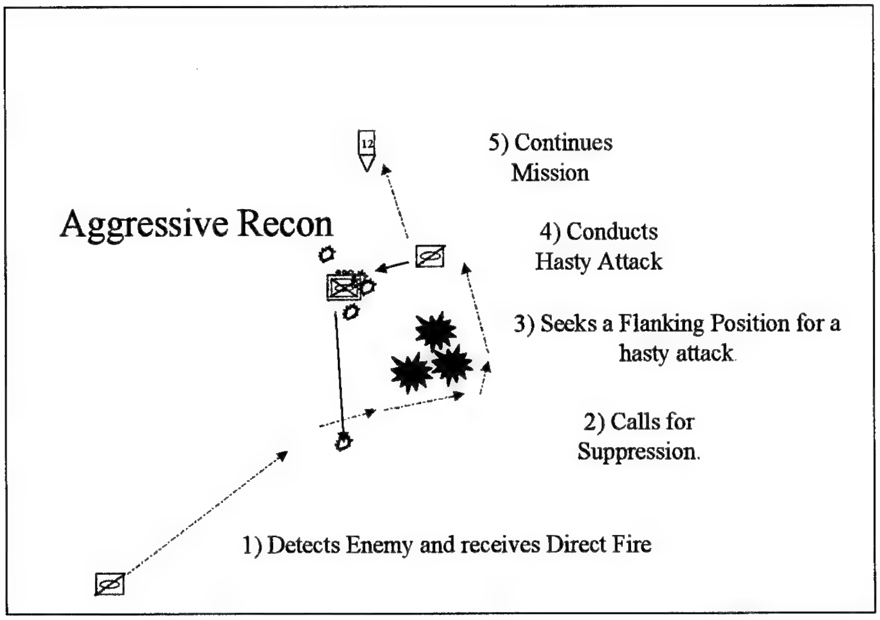

Figure 4.2: Aggressive Reconnaissance in the Tracer Recon FSM

Upon contact with the enemy, which will likely occur well before the enemy can detect the scout; the scout might initiate an indirect fire strike on the target, destroying the threat. Based on an increased ability to detect and identify the enemy, the scout might also maneuver to the enemy units' flanks and engage the threat with direct fire weapons before the enemy can detect him and then move on to continue the reconnaissance objective. A good C4I capability may render the reporting of accurate information almost automatic. Improved sensors may also render most dismounted reconnaissance unnecessary in other than urban or underground environments. However, the means to model the aggressive behavior in ModSAF will be to vary the weapons control status of the units and the targets that they are allowed to fire upon.

In ModSAF, the entity or unit can be set on Weapons Free, Tight, or Hold. These three settings allow the unit to react with weapons on contact with enemy entities differently. Weapons Free allows the unit to fire at targets at will, based on initial settings input by the user or by default settings set by the ModSAF program. Weapons Tight allows the entity to fire only when fired upon, according to the same list of enemy vehicles. Weapons Hold constricts the entity's ability to fire at any vehicle, regardless of the situation. For an Aggressive scout behavior, the Weapons Free command will be used allowing the scout to fire on all vehicles.

4.6 FSV Battalion Scout Platoon Tactics -- Passive Actions on Contact

The passive scout will enjoy very much improved stealth characteristics. With great C4I and impressive stealth technology, the scout should make contact well before the enemy can and should be able to bypass enemy units on the way to the reconnaissance objective. Indirect fire strikes may allow a hasty attack capability without significant chance for detection of the scout by the target.

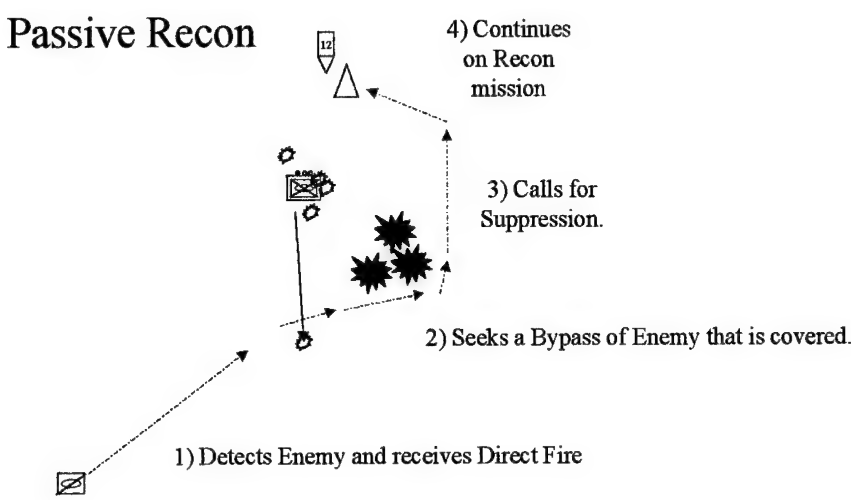

Figure 4.3: Passive Tactic in the Tracer Recon FSM

The passive scout will move on covered and concealed routes through enemy held territory without much chance of enemy detection. They will also refrain from direct fire contact on all targets. The Weapons Tight command will be used to simulate the passive behavior. They will use indirect fire to the maximum extent. Using C4I capability, they will paint the enemy picture for the battalion commander. The commander can then plan attacks and defenses with near perfect intelligence of the enemy and their intent.

With technological advances in sensor and C4I systems, both variants can, in theory, effectively gain and maintain contact with the enemy, without the threat of direct fire engagement. They could provide platforms for targeting enemy units with ever

increasingly accurate smart munitions, while still maintaining a military presence on the ground.

4.7 FSV Variants

What makes these weapons system technologically advanced? The FSV, sometimes referred to as the Future Scout Cavalry System (FSCS), is being tested to incorporate the latest in communications, sensor, weapons, and protection technology.

In a study on the incorporation of Intent as a reconnaissance metric, Lartigue (1998) conducted a study with five FSV variants. These variants range in attributes from the most advanced technology in stealth, protection and communications to a low-end variant that provided a simple upgrade to an existing weapons system. Two of the variants used in the Lartigue study are used in the analysis of the passive and aggressive behaviors. These variants are the Protect (the most suitable aggressive vehicle from the available set) and the Stealth (the most passive from the set) variants. The two variants have five categories of characteristics: Sensors, C4I/Communications, Vehicle Signature, Armor, and Main Weapon System.

4.7.1 Sensors

In the two systems, there are three categories of sensors: Commander's, Gunner's, and Driver's sensors. The driver's sensors are simply passive, VVS-2, or thermal driver's aides, DAS. The distributed aperture system (DAS) for the driver allows the driver to see close in targets and operate the vehicle in limited visibility using thermal technology.

The VVS-2 is a passive night sight using ambient light. It is currently in use in M1A1/2 and M3 fighting vehicles. It is less effective than the thermal sight in most situations.

The Commander's sensors are mounted on a mast. There are five different types: 2nd generation Forward Looking Infrared, (FLIR), 3rd generation FLIR, Radar, Acoustic, and Ladar. The 2nd Generation FLIR gives the scout commander a good chance of identification at 3-4 kilometers. This sight is mounted on top of a 6-15 meter mast that is erected when stationary and scans a 360-degree arc. The 3rd generation FLIR gives the scout a good chance of identification at 5 to 6 kilometers. Radar is a means to detect the presence of targets and operates in conjunction with other sensors. It is an active sensor that gives out a signature. Acoustic sensors detect and identify targets using sound by capturing the audio signature.

The gunners in both variants use a 2nd generation FLIR that is representative of the M1A2 Commander's Independent Thermal Viewer (CITV). This sight allows the Commander to search independently of the gunner while the gunner engages targets (Lartigue, 1998, p.35).

4.7.2 C4I/Communications

There are three categories of communications used in the FSV variants--Communication, Situational Awareness, and Terrain Reasoning.

Communication

Communication is the scouts primary weapon system. The scout exists to provide the Commander with information and without the communication that information

arrives in an untimely manner. Communication is also a weapon system. The scout uses accurate timely information to deliver calls for fire (CFF). In the FSV variants, there are three levels of communication. These levels were developed in the work by Lartigue (1998).

Level 1: This level affords the scout only current communication capability of FM voice transmissions.

Level 2: This level gives the scout digital reporting and CFF capabilities. With this system he can generate digital reports and send them much faster. This system is comparable with Integrated Vehicle Information System (IVIS) on M1A2s.

Level 3: This system has the capability of digital communications described above with the added feature of automated report generation. Once a sensor gains contact, this system automatically generates a report and sends it higher or for a CFF after vehicle commander's review. It is much faster and more accurate than current systems. This is comparable with the advanced Applique' C4I system that has been developed to full capacity as currently envisioned on the digital battlefield from Army After Next doctrine.

Situational Awareness

Situational Awareness is a common picture of the battlefield. Imagine a map with the precise current locations of all friendly units coupled with exact current enemy contacts and vehicle types. That is perfect situational awareness. The Army is currently fielding a situational awareness (SA) system called FBCB2, also called Applique', mentioned earlier. This capability will increase the scout's ability to move through the

battle area in the conduct of his mission and afford him protection from friendly fratricide incidents. This also allows the scout to more effectively track contacts. The levels of SA in the Tracer Recon ModSAF model, according to Lartigue (p.36) are:

Level 1: A map and a notepad. The most widely used current method. Contacts are recorded manually.

Level 2-4: Varying levels of electronic SA. For this study, level 2 can track 10 contacts, level 3 can track 15 contacts, and level 4 can track 20 contacts.

Level 5: This level tracks 20 contacts and allows for automatic update by the sensor system.

These modeled levels take advantage of existing ModSAF capabilities. They allow a scout to "remember" a list of detected entities. This is a simple model of crew or digital memory.

Terrain Reasoning

Automatic Terrain Reasoning affords the scout assistance in finding the best route of a FSV and looks for possible cover according to a digital terrain database.

4.7.3 Armor Protection

For aggressive behavior, physical protection may be more important than passive behavior in a scout. The varying levels of armor protection in this study are based on the levels of protection in current weapon systems. There are two protection levels: M113 and M3. The M113 provides small arms and shrapnel protection up to 7.62mm machine

gun. It is not very robust and can be defeated by most anti tank systems. M3 protection is more robust and can withstand hits up to 20 mm and some light anti-tank weapons.

4.7.4 Weapons Systems

The FSV variants all have a weapon for protection and destruction of enemy vehicles and infantry. The weapons used are 35 mm and 45 mm chain guns, that are like a large machine gun. They are capable of firing high explosive and armor-piercing ammunition in bursts or one round at a time.

There is an issue with ModSAF in relation to direct fire interaction between entities. The model does not model two important attributes of direct fire interaction. It does not take weapon visual or audio signature into account when an entity is attempting to detect targets. For example, if an enemy vehicle fires at a scout vehicle, the probability of the scout to detect that target will not increase due to the weapons signature effects, i.e. the flash (smoke, heat, and flash) and noise from the firing.

Detecting weapons is an important part of the scout's ability to find the enemy. There is also no collective ability for one scout to "see" a enemy unit fire at a different friendly scout. I see this as a need for further research in the ModSAF model. .

This issue may skew the possible results of the experiment, however, since the model misbehaves for all entities this effect may be mitigated. The model does, however, account for a higher threat level given to a target if the target is already detected. For, example, if a scout vehicle has two T80 tanks detected, but they have not fired upon it, they present an equal threat. If one fires, the scout vehicle recognizes the firing T80 as a higher threat. It does not increase the level of detection based on the weapons signature.

4.8 Variant Systems Characteristics

There are many more combinations of sensor, protection, and weapons systems than listed below, however, due to industrial and operation considerations only two combinations are of interest in this experiment. This thesis uses two FSV variants that will be tailored to perform the reconnaissance mission-- Protect and Stealth. Table 4.1 shows the variants capabilities:

Table 4.2. Variant Characteristics.

Variant	**Stealth**	**Protect**
Sensors:		
Commander	Gen 3 FLIR	Gen 2 FLIR
	Acoustic	Radar
Gunner	Gen 2 FLIR	Gen 2 FLIR
Driver	DAS	VVS-2
Mast Height	10 m	10 m
C4I:		
Communication	Level 2	Level 2
Situational Awareness	Level 4	Level 3
Terrain Artificial Intelligence	Yes	Yes
Vehicle Signature:	Very Low	Low
Armor:	M113	M3
Main Gun:	35 mm	45 mm

4.8.1 Protect FSV Variant

The Protect FSV is the more robust than the Stealth variant. It has a 10m mast. Its C4I capability is level 2 communications with an SA of level 3. It also has terrain following AI. It has a 2^{nd} generation FLIR for both the commander and gunner and has Radar and acoustic sensors. It has a 45mm main gun, but has heavier armor. The driver also has the ambient light VVS-2 night driving aide.

4.8.2 Stealth End Variant

The Stealth FSV is the designed to be more passive than the Protect variant. It also has a 10m mast. Its C4I capability is level 2 communications with a slightly higher level of SA, level 4. Like the Protect variant, it has terrain following AI. It also has a very low external signature, based on signature control technology. It has a 2nd generation FLIR for the gunner and a 3rd generation FLIR and acoustic sensors for the commander. It has a 35mm main gun and has light armor. The driver also has the thermal DAS night driving aide, which allows the driver to assist in spotting close in targets.

4.9 Ft Knox Hasty Attack Scenario

Due to limited resources, only one scenario was considered. The scenario was set in Fort Knox and portrays a variety of scout tasks in offensive operations. The scenario will use a form the Fort Knox digital terrain database. The mission will focus on offensive scout tasks to test actions on contact behaviors in a consistent manner--moving scout forces against stationary and moving defenders. The intent of the research is to develop a scenario that tests the scout's ability to detect and identify enemy forces that are in doctrinally correct and advantageous positions. The ability of the scouts to identify and destroy enemy reconnaissance screens will also be measured.

According to a RAND study conducted at the National Training Center, there is strong correlation between reconnaissance success, in gaining information about the enemy, and the supported friendly force's mission success (Goldsmith, 1987, p.32). This

suggests that the failure of the scouts to accomplish their mission will result in a less favorable loss exchange ratio for the friendly blue forces, if loss exchange ratio is a part of that mission success. Other measures of effectiveness for these scenarios are blue scout losses vs. red scout losses, blue vs. red total losses, and the measure of enemy intent achieved.

The rest of the section introduces the scenario, the general situation, friendly and enemy forces, the mission of scout platoon in relation to the supported battalion/task force, and the particular design used to develop measurements of effectiveness (MOE) and balance between the opposing forces. The intent is to create a scenario with a scout measurement space. The variants in the scenario and variant behaviors vary in the model.

4.9.1 General Situation

A Blue Tank battalion attacks a motorized rifle company in hasty defensive positions on a Fort Knox terrain. The scenario includes the new Army tank battalion organization, which has only three tank companies. The Blue attack is occurring towards a hasty defensive position based on a water obstacle. See Figure 4.4.

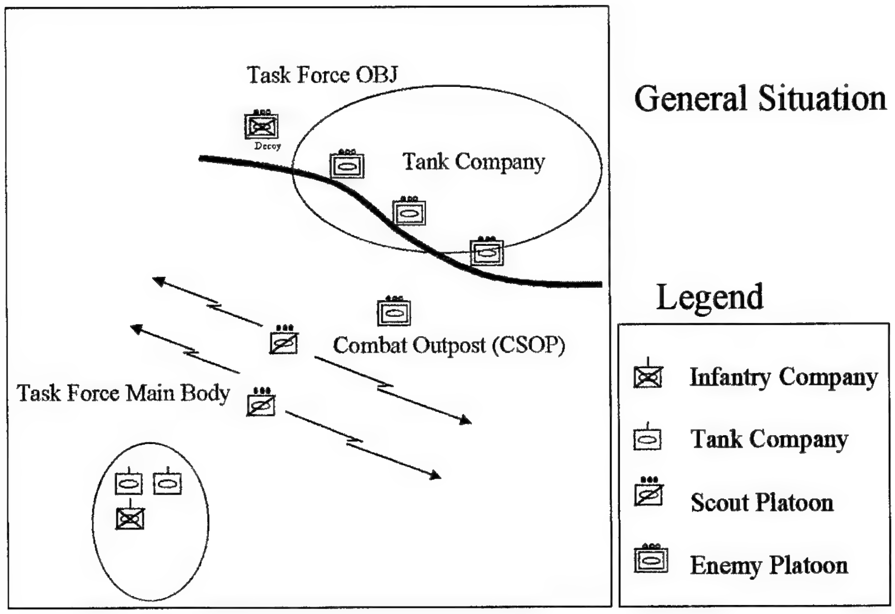

Figure 4.4: General Scenario Situation

4.9.2 Enemy Situation

The Red force is doctrinally arrayed with reconnaissance elements forward screening the combat outpost (CSOP). The CSOP is located forward of the tank company and its mission is to destroy Blue scouts, identify the enemy main body, and force the enemy (Blue force) to deploy too early, slowing the Blue force down. The Red tank company is arrayed in a line or platoon formations with a weak and strong side. The tank platoons are in a hasty defensive posture, continuing to prepare their positions. There are no enemy minefields deployed, as the Red force has just arrived in position. The Red forces are using decoy vehicles to bolster the appearance of strength in the north, which is the more difficult area to cross for the Blue forces and therefore the least

likely course of action (COA). There is a 6 gun 122mm howitzer battery supporting the Red force.

The main strength of the Red defense is in the south behind and supporting the CSOP made up of a tank platoon. Because of the dangerous position of the hasty defensive line the tank battalion commander has sent his tank platoon reserve to repel any breakthrough. The battalion commander believes that the defense of the water obstacle is a critical point in the defense. The Red tank platoon mission is to counterattack into the Red tank company position, if the Blue force has crossed the water obstacle and is preparing to assault the objective.

4.9.3 Blue Situation

The balanced task force is equipped with 24 M1A2 tanks and 14 M2 Bradley Fighting Vehicles. This is the traditional 58 tank or mechanized vehicle battalion minus one 14 tank company and plus a mechanized infantry company. A M106A6 Paladin Artillery battery supports the Blue battalion. The Blue tank battalion mission is to attack and destroy the Red tank company. The battalion will seize a critical ford in a small stream allowing the follow on tank battalion to pass through and seize the brigade objective.

4.9.4 Scout Mission

The scouts mission is to conduct a zone reconnaissance to the battalion objective, identifying all enemy reconnaissance elements and the CSOP, conduct an area reconnaissance of the objective and identify all defending platoons. The scouts will then

find an appropriate crossing site and infiltrate the objective, attempting to seek out any Red counterattack forces and indirect fire assets.

The key to this scenario for the scouts is survival through the Red counter reconnaissance screen, past the CSOP and through the main battalion objective. First, the scouts must find and use their particular tactics to destroy or bypass the CSOP and all reconnaissance elements. Destroying the CSOP allows the tank battalion freedom to maneuver along the axis of advance. Bypassing the CSOP allows the scouts to get into good observation posts and call indirect fire on the enemy main body forces. Next, the scouts must identify and infiltrate the objective. They must identify any counterattack forces. If they do so, they may allow the battalion to correctly attack a weakness in the enemy MRC defense. The scouts may also attritt the counter attack forces and allow the battalion time to seize the objective. If the scouts are not successful, the battalion will be attrited by the CSOP, the tank company, and any counterattacking tank platoon.

4.10 Scenario Verification

In devising the final experimental scenario, test scenarios were designed to verify the actions and movements of the semi-automated forces. Three ideas were developed to improve the collective nature of the existing ModSAF model. A test scenario was created and analyzed to determine the level of intent gained by the different variants, two possible Blue force courses of action, and possible Red force counter action to the Blue force movements. Twelve developmental runs, three for each different vehicle and tactic, for all ruins conducted were analyzed to determine the actual timing of forces, routes and courses of action in the final experimental scenario. The development run indicated that

the initial movement timing of the Blue Force main body varies by scout variant-type. The 40 % level of intent gained by the different variants determines, proportionally, which COA the variant will use. The timing of the red counterattack forces is based on the detection of the Blue scouts or main body forces. The next three sections discuss the three features in more detail.

4.10.1 Movement Variations According to FSV Variant

To account for the differences in the variant's capabilities, each variant required a slightly different scenario. The research varies the timing of the blue force main body movement based on the variant's detection of the CSOP and the red main defensive line. Table 4.3, highlights the movement times observed in the test scenarios for each variant. These times are in minutes from the start of the scenario. The scouts initiate movement at the zero minute time.

Table 4.3. Scenario Variations in Timing by Variant

		Protect	Stealth
Time	Action		
Detect CSOP	Move Task Force	40 min	30 min
Blue Main Body Detected	BN CTK	40 min	50 min

4.10.2 Proportion of Course of Action Runs Based on the Detection of Enemy Units

Cooperative behavior (See Section 4.4) is not well modeled in ModSAF (Hoff and Lee, 1998). As another example, in a real armored battalion there is a commander that controls the organization. He commands the scout platoon and the subordinate tank

and infantry companies. He directs the scout platoon to find information about the enemy that he uses to refine his battle plan, based on previous enemy estimates by his staff. His battle plan makes assumptions about the enemy situation, that once confirmed, act as a confirmation of the plan, or require a change in his plan. The scout platoon ability to find information about the enemy on the battlefield can be directly correlated to the success or failure of the battalion's plan. It is not the only factor, but it can spell success or defeat.

In ModSAF, the battle plan is created by the scenario developer and executed by the model. The scenario developer assigns tasks to the unit entities much like the battalion staff creates a battle plan. Tracer recon, discussed earlier, is a task that scout vehicles could receive. The scenario developer uses graphics that are similar to those used by a military unit in controlling its units, like check points and phase lines, to control the ModSAF unit entities. A planned series of tasks controlled by occurring events such as expiring time, messages from other entities, and other entities movement past or to graphic control measures, constitute the ModSAF battle plan.

Unlike reality, information is not shared between the scout platoon and the ModSAF battalion commander, as there is no real automated commander entity. With a live interacting commander, once the developer initiates the run, the model's entities interact in a random fashion according to these task lists, or "battle plans." The scout can detect and identify and intent as many units as there are enemy entities, and the other blue forces will not alter from the battle plan.

The effect of the scouts' information on the commander's battle plan can be simulated by changing the timing and maneuver of the battalion companies based on observed levels of intent in the scenario. For example, a particular FSV variant might gain 40 % level of intent on the enemy force in 20 minutes where it takes 30 minutes in another variant. The developer can change the task list for that variant to reflect a potentially better course of action--attacking a weak spot in the defense--in a quicker amount of time. The real commander might also change his battle plan, or course of action, to a more favorable one in a shorter time in such a situation. This could result in a better outcome for several MOE's for that variant.

By observing a series of developmental runs, the levels of intent gained by the scout can be estimated before the true experimental runs are made. Changes to the experimental battle plan, or task list can then be made. Dr. Martin suggested that the COA be selected by the model according to the level of intent gained by the scouts by a certain time in the scenario. Since this is a Monte Carlo model, this varies from run to run. Being unable to automate this selction within the time frame of the research, a proportion based on observation of several tests runs was selected as an expedient alternative. The proportion of runs with the most advantageous COA was based on the amount of enemy intent gained by the commander by the 40 minute mark in the test scenarios. This time mark is based on giving the commander enough time to accomplish the mission, in this case two thirds of the total scenario time of 120 minutes.

In a hasty attack the commander must make the COA decision as soon as possible to allow the forces to accomplish their mission. There is no doctrinal rule in this case. A

commander's tactical judgement based on his previous military education and experience is the primary factor in his decision. Based on observations of the 12 initial replications, the 40 % level of intent also allowed the blue scouts to detect the weakness in the north. By gaining 40% intent, the scouts also detected all 6 red decoy entities. This is a key factor in the commander's decision to use COA A.

The variants are composed of varying degrees of C4I and sensors and therefore gained a slower or faster level of intent on the enemy based on their capabilities. One might expect the commander to get a very good picture of the enemy force earlier than the other variant. The Stealth tracer has very good C4I and sensors. To show this fuller common picture of the battlefield, the maneuver plan of the battalion changed between the more advantageous attack and the less advantageous attack.

The research modified the COA based on the ability of the variant to achieve a 40 % level of Intent. In this scenario, the attack is hasty in nature, but occurs and restrictive terrain. A commander can not afford to wait until he has perfect enemy dispositions or he might never choose to attack, or even choose too attack too late. Given the more difficult terrain in this scenario, this research used a 40% level of intent to determine the blue force COA. There is no answer to how much intent the commander should know before deciding on the enemy COA. It is part of the art of command. This research assumes that with 40% intent, the average commander could decide on and issue the orders for a new, more advantageous COA in a hasty attack. The 40 % level of intent defines the point in time that a commander would have to commit to one COA over another. If the variant attained a 40% level of intent on the enemy before 40 minutes in

the trial scenarios, they had a better chance of using COA A--the most advantageous COA.

The table below shows the proportional number of different COA runs accomplished by variant and by tactic, based on the initial level of intent. To clarify, the protect vehicle used COA A 40% of the time in its 40 runs, or 16 runs total. The Stealth used 100% COA due to its ability to gain a higher level of intent earlier in the test scenarios.

Table 4.4. Course of Action Simulation Runs by Variant

	Stealth	Protect
Time to 40% Intent	35 min	40+ min
COA A Runs	10	4
COA B Runs	0	6

COA A allowed the attackers to bypass the combat outpost in the south and attack across the stream in an area with less enemy strength. See Figure 4.5. The two supporting companies would destroy the weak forces in the north and pass the assault company through to attack each platoon in the south in turn. One supporting company would defend a position against the counterattack force that was being tracked by the scouts.

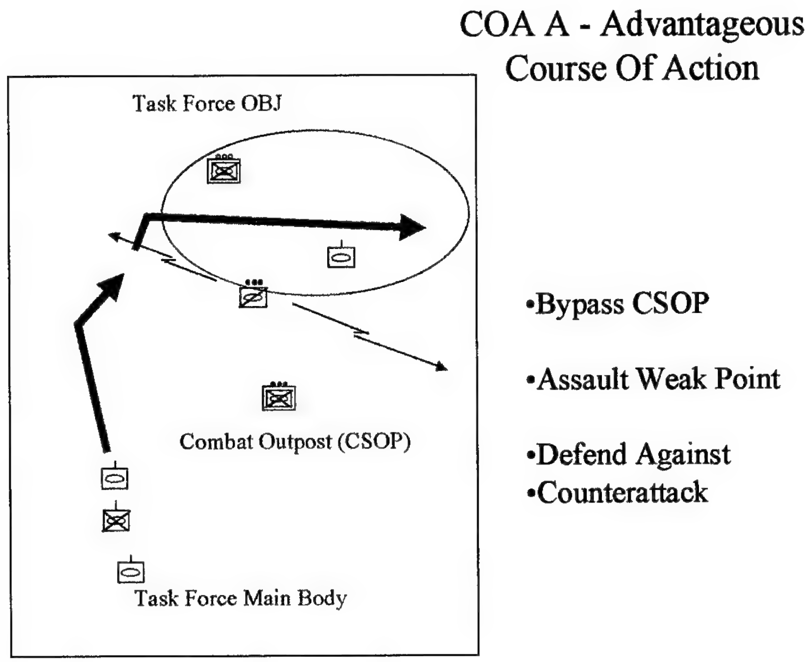

Figure 4.5. Course of Action A Description

COA B is the course of action that would be taken by the prudent commander that did not know of the weak point in the enemy defense. The two tank companies would bypass the CSOP and destroy it. They would then set up support by fire positions to suppress the enemy main defense while the assault mechanized infantry company moved into position to assault the enemy main defensive line. The assault would be accomplished by attacking a platoon at a time in the flank, with support from the other two companies. See Figure 4.6.

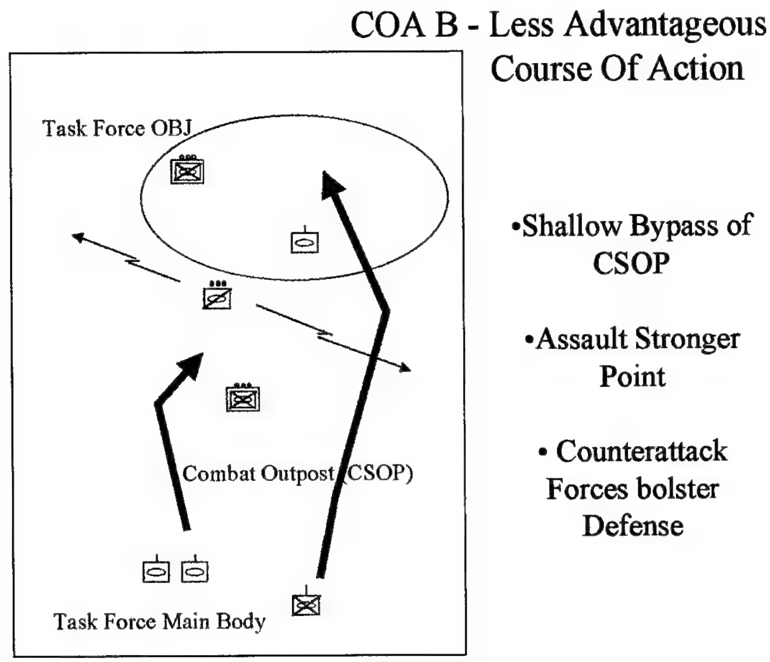

Figure 4.6. Course of Action B Description

4.10.3 Red Counterattack to Highlight Tracer Effectiveness

In the course of the scenario development, some scouts had less ability to maneuver undetected based on their physical characteristics. Protect variants were seen earlier than Stealth entities, for example. This was to be expected. The research needed to allow the Red force to gain a tactical advantage in the scenario design if the red force gained information on the Blue force activities.

To show this advantage, one local repositioning of forces and one battalion counterattack were added into the red force battle plan--one local and one battalion level. The local repositioning is launched as a result of the identification of two or more tracer recon vehicles in the area of the main blue attack. It is merely a repositioning of red main

forces to the area of the attack to strengthen the weaker forces in that area. Five to six T80UM tanks make the reposition, if alive at that point. This is a planned reposition, by the company commander to move remaining vehicles to their alternate positions within the battle position.

The battalion counterattack is a tank platoon sized (three tanks) counterattack sent by the battalion commander. This attack is launched as soon as the red forces identify the main body. The Blue scouts can affect this attack in several ways. If the red recon screen is destroyed, the time before the main body force is detected is greater, the counterattack comes later and the blue main body force can be in position to repel the attack. If detected in time, blue tracers can use precision guided munitions to destroy the counter attack force before the force engages the blue main body. The better able the FSV to detect and engage the force; the more effective it is and the higher the overall LER.

4.11 Building Direct and Indirect Fire Effectiveness into the Scenario Design

Another way to measure scout effectiveness is the scout entities' ability to engage and destroy enemy units with direct fire weapon systems. Using different variant characteristics and varying tactics, the different tracer entities should have varying levels of success in destroying enemy scouts and main defensive units. The more the scouts kill or disable, the less chance blue battalion entities will be destroyed before reaching their objectives. The overall LER should reflect a portion of scout direct fire success.

Also, the two FSV variants have different capabilities in calling indirect fire. Variants with higher levels of C4I have a greater capability to destroy enemy units before

blue main body entities can be engaged. There should be some correlation in the variant's ability to accurately call indirect fire and overall Blue losses, or the Loss Exchange Ratio.

The scenario deployed a Red scout screen of four entities two to four kilometers in advance of the first defensive positions. This enemy screening force can engage and destroy tracers and infantry fighting vehicles. They can also slow or disrupt the formations as they pass through this screen, using direct and indirect fires. The more capable the scout in destroying the enemy screen vehicles, the better able the Blue battalion to accomplish its mission.

4.12 Measures of Effectiveness (MOE)

Measures of effectiveness are used to compare the outcomes of two events. This section outlines the MOE's used to compare the tactical outcomes of the simulation runs.

4.12.1 Measuring Loss Exchange Ratios

Loss exchange ratios (LER) are used in military applications to show relative success. How many enemy systems destroyed vs. friendly losses can shed some light into the success of the scouts. If the scouts called for long range missiles or artillery and killed or disabled a large number of Red tanks in a counterattack force, the number of blue force losses might go down because the Red force that eventually made direct fire contact would be smaller. LER is traditionally a measure of Red over Blue losses.

4.12.2 Blue Scout Losses

Another measure might include a scout loss ratio. Total scout losses in one scenario are compared between the two behaviors. This may provide a good measure of behavior effectiveness. The two variants in the same scenario act on the opposite variant to reduce the variability of the vehicle characteristics on the experiment (i.e. use the aggressive behavior in the same scenario on the passive vehicles.)

4.12.3 Precision Weapons / Artillery Effectiveness

To show a further measure of scout effectiveness, the research will show the artillery and long range missile effectiveness of a scenario. There are two artillery MOE's, artillery kills and number of rounds fired. These MOE's measure the number of Red losses due to more effective communications systems, but also the ability of the scout to be in the position to call accurate indirect fires. The variant's C4I effects the accuracy of indirect fire calls for fire, but the survival of the systems allow the scout to be able to make those calls. The number of rounds fired to kill enemy forces over time may show some useful information on accuracy of the fire missions. Red forces also had a battery of 2S1 artillery pieces. They can also call for fire on the Blue forces. Their effectiveness will be limited due to the mobile nature of the Blue force in the attack.

4.12.4 Percent of the Total Enemy Force Detected vs. Identified

The ability of the scout to detect the enemy can also be measured. This is a factor of system position and sensor ability. The survival of the scouts effects this measure, as well. The amount of information gained from a scout on a detected target is based on the

Johnson's acquisition criteria. The four levels of acquisition of a target from the lowest to the highest are detection, classification, recognition, and identification (Johnson, 1958).

According to the Johnson criteria:

- Detection is acquisition of a target with no definition apparent.
- Classification is the ability to determine if the target is heavy or light, tracked or wheeled.
- Recognition is the determination of class of vehicle (which should determine friend or foe.)
- Identification is typing of vehicles as M-1, T-72, etc.

If a scout recognizes the vehicle as enemy or identified it for sure as the enemy, it calls for fire or engages the target with direct fire. The higher the percentage of identification, the more information available to the higher headquarters, thus a measure of scout's success. This leads to the final measure--Intent.

4.12.5 Measuring Intent

Lartigue (1998) argues for the use of intent as a reconnaissance metric. One of the important standard Army reports is given in the size, activity, location, unit, time, equipment (SALUTE) format. This is the mainstay report of the scout. This report includes information on unit, equipment and also activity. The scout's awareness of activity can be refined the longer the scout has observation on the target.

Intent can be measured by detailed identification of the enemy, the percent of the enemy force detected, timeliness, and a persistence in observation (Lartigue, 1998, p.24).

In his evaluation, the scout gains enemy intent after five minutes of persistent observation. Intent will be used in this research as a measure of a scout's effectiveness between the two behaviors. The ability for scouts to survive long enough to "intent" the enemy detected may be affected by the vehicles aggressive or passive behavior.

4.13 Considerations outside the Model

This experiment is limited in its ability to provide a complete understanding of the effects of real tactical behavior in actual combat. This experiment uses an accepted simulation model that has been modified to study the effectiveness of two reconnaissance behaviors. There are many combat effects that are not included in this study. As identified in Lartigue (1998), there was no use of land mines or nuclear, biological and chemical weapons. ModSAF also does not model the morale effects of military units in combat. The battlefield clutter that might be present on the modern battlefield, like automobiles, other civilian vehicles, and refugees, is also not modeled.

The statistical evidence presented by this experiment is not intended to be used alone in the development of tactics, rather, to be used in conjunction with other virtual and live simulation to refine and develop suitable reconnaissance tactical direction.

4.14 General Hypothesis Question

The Chapter Three overall research questions follow, "Is there a difference in tactical outcome due to the use of aggressive or passive land-based reconnaissance by different reconnaissance vehicle systems and can tactics and vehicle systems be developed concurrently?" Because of research asset and time constraints, the research

will explore the land reconnaissance question for US mechanized battalion, reconnaissance assets. The general hypothesis is that there is interaction between the type of reconnaissance tactic and type of reconnaissance vehicle used in battalion level land reconnaissance.

To further define this question, the effectiveness of the two reconnaissance behaviors and two vehicles over the four measures of effectiveness are compared using sub hypothesis questions. Three hypothesis questions are posed for each MOE.

4.14.1 Loss Exchange Ratio

The first LER hypothesis examines if there is interaction between vehicle-type and tactical behavior in the tactical outcome of battalion-level land based reconnaissance. See Table 4.5. This is based on a complete general linear model for the LER MOE. The other MOE's have a similar model associated with the first hypothesis.

$$MOE(LER)=\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2$$

This model includes two main effects terms and an interaction term. The X_1 term is the tactic effect. The X_2 term is the vehicle term and the last term is the interaction term. β_0 and other parameters represent the unknown parameters in the model. This model is the same for all four MOE's.

The null hypothesis is that there is no difference in the interaction on the main effects of the model. This is shown in Table 4.5. If there is no interaction between the

two factors, the second and third hypothesis, under each MOE, allow the researcher to determine if the main effects of tactics and vehicle-type provide statistically significant results.

The alternative hypothesis is that at least one parameter is different. This shows that there is interaction. If interaction is present, there is no reason to look at each main effect because each effect is influenced by its interaction with the other factors. The interaction allows one to compare the four treatments with each other.

In the case of LER, the expectation is for the stealth/aggressive treatment to provide a higher LER. The stealth/passive is next, then the protect/aggressive and then the protect/passive.

Table 4.5. LER Hypothesis One: Interaction between behavior and vehicle variant.

Null Hypothesis	H_o: $B_1=B_2=B_3$
Alternative Hypothesis	H_a: At least one parameter is different.

The second LER hypothesis examines if there is difference in the tactical outcome based on tactical behavior main effect of land-based reconnaissance. Based on the vehicle capabilities and the model, the alternative hypothesis is that the Aggressive behavior will produce a higher sample mean than the Passive behavior. While the null hypothesis is that the Passive behavior is greater than or equal to the Aggressive behavior sample mean. See Table 4.6.

Table 4.6. LER Hypothesis Two: Tactics

Null Hypothesis	H_o: $\mu_{\text{tactics (aggressive)}} <= \mu_{\text{tactics (passive)}}$
Alternative Hypothesis	H_a: $\mu_{t(a)} > \mu_{t(p)}$

The third LER hypothesis examines if there is a difference in the tactical outcome based on variant-type in battalion sized land-based reconnaissance. For LER, the alternative hypothesis is that the Stealth vehicle is greater than the LER for the Protect vehicle sample mean. The null hypothesis is that the Protect vehicle is greater than or equal to the Stealth vehicle sample mean. See Table 4.7.

Table 4.7. LER Hypothesis Three: Tracer Variants

Null Hypothesis	H_o: $\mu_{\text{vehicle\_type (stealth)}} <= \mu_{\text{vehicle\_type (protect)}}$
Alternative Hypothesis	H_a: $\mu_{v(s)} > \mu_{v(p)}$

4.14.2 Scout Losses

The first Scout losses hypothesis examines if there is interaction between vehicle-type and tactical behavior in the tactical outcome of battalion-level land based reconnaissance. See Table 4.8. This is based on the same model introduced for LER.

The null hypothesis for the first question is that all the parameters in the model are the same. This shows that there is no interaction. If there is no interaction, the

second and third hypotheses allow the researcher to determine if the main effects of tactics and vehicle-type provide statistically significant results. The alternative hypothesis is that there is at least one parameter in the model that is different. If interaction is present, there is no reason to look at each main effect because each effect is affected by its interaction with the other factors. Once again, the interaction allows one to compare the four treatments with each other.

For the Scout losses MOE, the expectation is for the protect/aggressive treatment to provide a higher scout losses sample mean. The stealth/aggressive is next, then the protect/passive and then the stealth/passive.

Table 4.8. Scout Losses Hypothesis One: Interaction between behavior and vehicle variant.

Null Hypothesis	H_o: B_1=B_2=B_3
Alternative Hypothesis	H_a: At least one parameter is different.

The second Scout Losses hypothesis examines if there is difference in the tactical outcome based on tactical behavior main effects in battalion sized land-based reconnaissance. Based on the vehicle capabilities and the model, the alternative hypothesis is that the Aggressive behavior will produce a higher scout losses sample mean than the Passive behavior. The null hypothesis is that there the Passive behavior will be equal to or greater than the Aggressive behavior. See Table 4.9.

Table 4.9. Scout Losses Hypothesis Two: Tactics

Null Hypothesis	H_o: $\mu_{\text{tactics (aggressive)}} <= \mu_{\text{tactics (passive)}}$
Alternative Hypothesis	H_a: $\mu_{t(a)} > \mu_{t(p)}$

The third Scout Losses hypothesis examines if there is a difference in the tactical outcome based on variant-type in battalion sized land-based reconnaissance. The alternative hypothesis, in this case, is that the Protect vehicle mean is greater than the Protect vehicle sample mean. See Table 4.10. This is expected because the Protect vehicle is less stealthy than the Stealth vehicle and therefore, might be detected and destroyed at a higher rate.

Table 4.10. Scout Losses Hypothesis Three: Tracer Variants

Null Hypothesis	H_o: $\mu_{\text{vehicle\_type(protect)}} <= \mu_{\text{vehicle\_type(stealtht)}}$
Alternative Hypothesis	H_a: $\mu_{v(p)} > \mu_{v(s)}$

4.14.3 Artillery Kills

The first Artillery Kills hypothesis examines if there is interaction between vehicle-type and tactical behavior in the number of artillery kills in battalion-level land based reconnaissance. See Table 4.11.

If there is no interaction, the second and third hypotheses allow the researcher to determine if the main effects of tactics and vehicle-type provide statistically significant results.

If interaction is present, there is no reason to look at each main effect because each effect is affected by its interaction with the other factors. Again, the interaction allows one to compare the four treatments with each other. For the Artillery Kills MOE, the expectation is for the Stealth/Passive treatment to provide a higher artillery kills' sample mean. The protect/passive is next, then the stealth/aggressive and the protect/aggressive.

Table 4.11. Artillery Kills Hypothesis One: Interaction between behavior and vehicle variant.

Null Hypothesis	H_o: $B_1=B_2=B_3$
Alternative Hypothesis	H_a: At least one parameter is different.

The second Artillery Kills hypothesis examines if there is a difference in the tactical outcome based on tactical behavior in battalion sized land-based reconnaissance. Based on the vehicle capabilities and the model, the hypothesis is that the Passive behavior will produce a higher sample mean than the Aggressive behavior. See Table 4.12. This is expected because the Aggressive vehicles may kill the enemy vehicle before the indirect fire even impacts with Aggressive behavior, this might lead Passive behavior to have a higher sample mean.

Table 4.12. Artillery Kills Hypothesis Two: Tactics

Null Hypothesis	H_o: $\mu_{\text{tactics (passive)}} <= \mu_{\text{tactics (aggressive)}}$
Alternative Hypothesis	H_a: $\mu_{t(p)} > \mu_{t(a)}$

The third Artillery Kills hypothesis examines if there is a difference in the tactical outcome based on variant-type in battalion sized land-based reconnaissance. For Artillery Kills, the Stealth vehicle is hypothesized to be greater than the Artillery Kills for the Protect vehicle sample mean. See Table 4.13. Higher levels of C4I for the Stealth vehicle may effect this outcome.

Table 4.13. Artillery Kills Hypothesis Three: Tracer Variants

Null Hypothesis	H_o: $\mu_{\text{vehicle\_type (stealth)}} <= \mu_{\text{vehicle\_type (protect)}}$
Alternative Hypothesis	H_a: $\mu_{v(s)} > \mu_{v(p)}$

4.14.4 Scout Direct Fire Kills

Again, the first Scout Direct Fire hypothesis examines if there is interaction between vehicle-type and tactical behavior in the tactical outcome of battalion-level land based reconnaissance. See Table 4.14.

If there is no interaction, the second and third hypothesis allow the researcher to determine if the main effects of tactics and vehicle type provide statistically significant results.

If interaction is present, there is no reason to look at each main effect because each effect is affected by its interaction with the other factors. Interaction allows one to compare the four treatments with each other. For the Scout Direct Fire Kills MOE, the expectation is for the Protect/Aggressive treatment to provide the highest scout direct fire kill sample mean. The Stealth/Aggressive is next, then the Stealth/Passive and then the Protect/Passive.

Table 4.14. Scout Direct Fire Kills Hypothesis One: Interaction between behavior and vehicle variant.

Null Hypothesis	H_o: B_1=B_2=B_3
Alternative Hypothesis	H_a: At least one parameter is different.

The second Scout Direct Fire hypothesis examines if there is difference in the tactical outcome based on tactical behavior while confounding the effects of variant-type in battalion sized land-based reconnaissance. Based on the vehicle capabilities and the model, the expectation is that the Aggressive behavior will produce a higher sample mean than the Passive behavior. See Table 4.15.

Table 4.15. Scout Direct Fire Kills Hypothesis Two: Tactics

Null Hypothesis	H_o: $\mu_{\text{tactics (aggressive)}} <= \mu_{\text{tactics (passive)}}$
Alternative Hypothesis	H_a: $\mu_{t(a)} > \mu_{t(p)}$

The third Scout Direct Fire hypothesis examines if there is a difference in the tactical outcome based on variant-type while confounding the effects of tactics in battalion sized land-based reconnaissance. For Scout Direct Fire Kills, the Protect vehicle is hypothesized to be greater than the Scout Direct Fire Kills for the Stealth vehicle sample mean. See Table 4.16

Table 4.16. Scout Direct Fire Kills Hypothesis Three: Tracer Variants

Null Hypothesis	H_o: $\mu_{\text{vehicle\_type (protect)}} <= \mu_{\text{vehicle\_type (stealth)}}$
Alternative Hypothesis	H_a: $\mu_{v(p)} > \mu_{v(s)}$

The next chapter discusses the results of the research.

CHAPTER 5

ModSAF SIMULATION RESULTS, AND EVALUATION OF AGGRESSIVE AND PASSIVE SCOUT PLATOON TACTICS

5.1 Introduction

This chapter first addresses the general linear model in more detail and then discusses the results of each set of the simulation runs. As mentioned earlier, the experiment was a 2 x 2 factorial experiment. To determine interaction in each of the four MOE's, an analysis of variance (ANOVA) was conducted. If the results show interaction, the four factors were compared to each other. If there was no interaction, the main effects could be compared with the second and third hypothesis questions. Run results are discussed in four cases, one for each MOE. These cases coincide with the hypothesis in Chapter Four. For each MOE the results of the three hypothesis questions are discussed.

The MOE's that deal with losses on both sides--scout losses, artillery kills, and scout direct fire kills-- are all normalized on a zero to one scale, one being the highest rating. LER is not normalized

5.2 ANOVA/General Linear Model

The main research question was, "Is there a difference in tactical outcome due to the use of aggressive or passive land-based reconnaissance by different reconnaissance vehicle systems and can tactics and vehicle systems be developed concurrently?" The research compares the contribution of tactical behavior and vehicle-type by examining a complete model that includes the interaction of the cases on the measure of tactical effectiveness, or MOE. The two factors are tactical behavior and vehicle-type. Each independent variable, or factor, has two levels--aggressive and passive tactics; and stealth and protect tracer variants. Two indicator variables are used-- X_1 for tactical behavior and X_2 for vehicle-type. A 1, 2 relationship in each independent variable indicates which level of independent variable influences the response variable. For example, $X_1 = 1, X_2 =2$ would be the MOE for 20 aggressive tactic and protect variant replications. The first order general linear model is:

$$MOE=\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2$$

5.3 Discussion on Results by Case

In this section, the results of each MOE will be presented. The Loss Exchange Ratio is first, followed by the Scout Losses, the Artillery Kills and then the Scout Direct Fire Kills.

5.3.1 Loss Exchange Ratio

The first LER hypothesis from Chapter Four examines if there is interaction between vehicle-type and tactical behavior in the tactical outcome of battalion-level land based reconnaissance. Table 5.2 shows the results of the complete general model ANOVA.

Table 5.1. LER Hypothesis One: Interaction between behavior and vehicle variant.

Null Hypothesis	H_o: $B_1=B_2=B_3$
Alternative Hypothesis	H_a: At least one parameter is different.

Table 5.2: LER General Model ANOVA

Predictor	Coefficient	F-Value	P-Value
Constant	4.8960		
Vehicle	2.3105	15.52	0.00000
Tactic	1.1735	4.00	0.051
Vehicle and Tactic	0.8420	2.06	0.155

The Interaction effect p-value of 0.155 does not fall in the rejection region for a 95 % confidence interval. One can fail to reject the null hypothesis that all the parameters are equal in this case. This means that there is no interaction. In the interaction plot in Figure 5.1, one can learly see that there is no interaction.

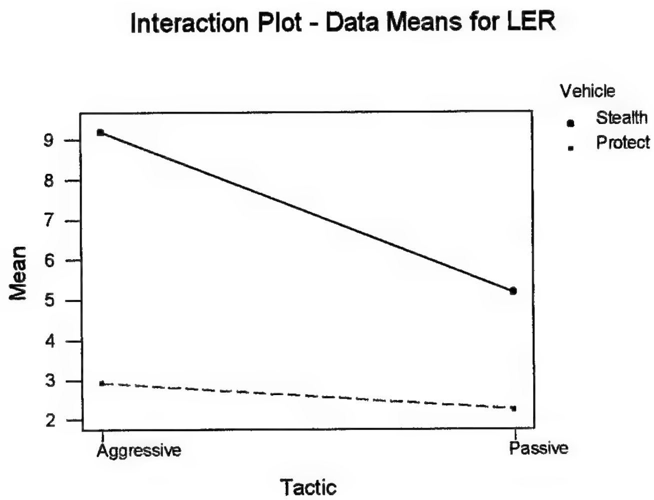

Figure 5.1: LER Interaction Plot

No interaction leads to the next two hypothesis statements. Because there was no interaction, the complete general linear model could not be used. The reduced linear model, shown below, is used to compare the main effects to answer the hypothesis questions.

$$LER = 15.3 - 2.35\ X_t - 4.62\ X_v$$

The second LER hypothesis examines if there is difference in the tactical outcome based on tactical behavior main effect of land-based reconnaissance. See Table 5.3.

Table 5.3. LER Hypothesis Two: Tactics

Null Hypothesis	H_o: $\mu_{\text{tactics (aggressive)}} <= \mu_{\text{tactics (passive)}}$
Alternative Hypothesis	H_a: $\mu_{t(a)} > \mu_{t(p)}$

The third LER hypothesis examines if there is a difference in the tactical outcome based on variant-type while confounding the effects of tactics in battalion sized land-based reconnaissance. See Table 5.4.

Table 5.4. LER Hypothesis Three: Tracer Variants

Null Hypothesis	H_o: $\mu_{\text{vehicle\_type (stealth)}} <= \mu_{\text{vehicle\_type (protect)}}$
Alternative Hypothesis	H_a: $\mu_{v(s)} > \mu_{v(p)}$

To answer the two hypothesis questions the reduced general linear model is analyzed. The result of the reduced general linear model is shown in Table 5.5. The test for statistical significance is done first and then the main effects can be compared if there is statistical significance.

Table 5.5: LER Reduced Model Results

Predictor	Coefficient	t-value	p-value
Constant	15.348	5.96	0.00000
Tactic	-2.347	-1.99	0.05
Vehicle	-4.621	-3.91	0.000

The vehicle factor has statistically significant results based on a 95 % C.I. This allows one to compare resulting sample means of each main effect separately. The tactics also has significant results, but the results are close enough to the rejection region

to question, especially given the ModSAF detection issue mentioned in Section 4.7.4. As a result, the Tactic means will not be shown. The Vehicle data, however, rejects the null hypothesis. The Stealth sample mean is greater than the Protect variant mean. Table 5.6 shows the results of this comparison.

Table 5.6: LER Reduced Model Means Comparison.

Factor	LER Sample Mean
Stealth	7.2106
Protect	2.586

The results of the reduced general linear model only have an R-squared value of 22.1% with an adjusted R-squared value of 19.1%. The ANOVA results show that only the vehicle main effect has an effect on the LER and there is no interaction between the tactic and the weapon system.

5.3.2 Scout Losses

The Scout Losses Interaction hypothesis from Chapter Four examines if there is interaction between vehicle-type and tactical behavior for Scout Losses MOE of battalion-level, land based reconnaissance. Table 5.8 shows the results of the complete general model ANOVA.

Table 5.7. Scout Losses Hypothesis One: Interaction between factors.

Null Hypothesis	H_o: $B_1=B_2=B_3$
Alternative Hypothesis	H_a: At least one parameter is different.

Table 5.8: Scout Losses General Model ANOVA

Predictor	Coefficient	F-Value	p-Value
Constant	0.04063		
Tactic	-0.00312	0.03	0.859
Vehicle	0.02188	1.55	0.216
Vehicle Tactic	0.01562	0.79	0.376

The Interaction effect p-value of 0.376 does not fall in the rejection region for a 95 % confidence interval. One fails to reject the null hypothesis that all the parameters are equal in this case. This means that there is no statistically significant interaction. In the interaction plot in Figure 5.2, one can clearly see that there is no interaction.

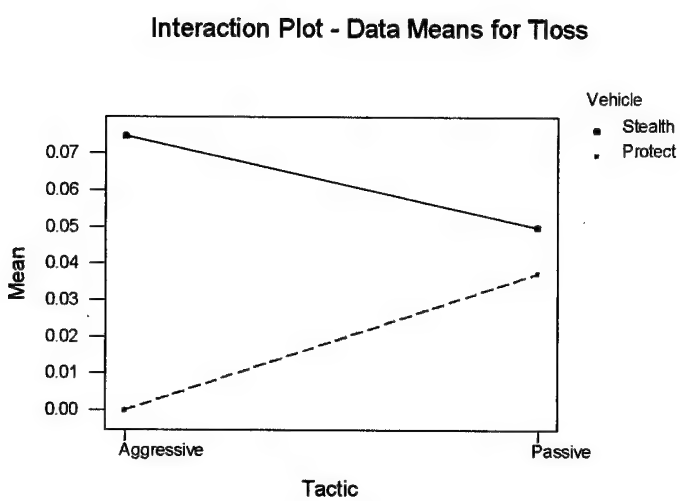

Figure 5.2: Scout Losses Interaction Plot

No interaction leads to the next two hypothesis statements. Because there was no interaction the interaction term was discarded and the reduced linear model, shown below, is used to compare the main effects to answer the hypothesis questions.

$$\text{Scout Losses} = 0.0969 + 0.0062\, X_t - 0.0438\, X_v$$

The Tactical hypothesis examines if there is difference in the tactical outcome based on tactical behavior main effect of land-based reconnaissance. The expectation is that the Aggressive behavior will produce a higher sample mean than the Passive behavior. See Table 5.9.

Table 5.9. Scout Losses Hypothesis Two: Tactics

Null Hypothesis	H_o: $\mu_{\text{tactics (aggressive)}} <= \mu_{\text{tactics (passive)}}$
Alternative Hypothesis	H_a: $\mu_{t(a)} > \mu_{t(p)}$

The third hypothesis examines if is a difference in the tactical outcome based on variant-type while confounding the effects of tactics in battalion sized land-based reconnaissance. For Scout Losses, the Protect vehicle is expected to have more Scout Losses than the Stealth vehicle. See Table 5.10.

Table 5.10. Scout Losses Hypothesis Three: Tracer Variants

Null Hypothesis	H_o: $\mu_{\text{vehicle\_type (protect)}} <= \mu_{\text{vehicle\_type (stealth)}}$
Alternative Hypothesis	H_a: $\mu_{v(p)} > \mu_{v(s)}$

To answer the two hypothesis questions the reduced general linear model is analyzed. The result of the reduced general linear model is shown in Table 5.11. The test for statistical significance is done first and then the main effects can be compared if there is statistical significance.

Table 5.11: Scout Losses Reduced Model Results

Predictor	Coefficient	t-value	p-value
Constant	0.09689	1.27	0.208
Tactic	0.00625	0.18	0.8959
Vehicle	-0.04375	-1.25	0.216

The two factors are both not statistically significant based on a 95 % C.I. There can be no comparison of the means because the main effects are not statistically significant.

One fails to reject both null hypothesis because there is not enough statistical difference in the main effects. The reduced general linear model has an adjusted R-squared value of 0.0%. The ANOVA results show that vehicles and tactics both have no effect on the scout losses. There is no interaction.

5.3.3 Artillery Kills

The Interaction hypothesis from Chapter Four examines if there is interaction between vehicle-type and tactical behavior for the Artillery Kills MOE. Table 5.13 shows the results of the complete general model ANOVA.

Table 5.12. Artillery Kills Hypothesis One: Interaction between factors.

Null Hypothesis	H_o: $B_1=B_2=B_3$
Alternative Hypothesis	H_a: At least one parameter is different.

Table 5.13: Artillery Kills General Model ANOVA

Predictor	Coefficient	F- Value	p-value
Constant	0.35729		
Tactic	-0.03229	1.79	0.185
Vehicle	0.19687	66.62	0.0000
Vehicle Tactic	-0.03021	1.57	0.214

The Interaction effect p-value of 0.214 does not fall in the rejection region for a 95 % confidence interval. One fails to reject the null hypothesis that all the parameters are equal in this case. This means that there is no statistically significant interaction. In the interaction plot in Figure 5.3, one can clearly see that there is no interaction.

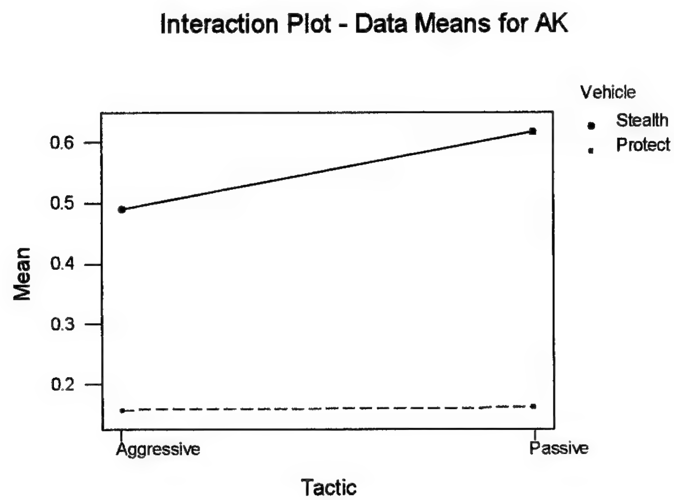

Figure 5.3: Artillery Kills Interaction Plot

No interaction leads to the next two hypothesis statements. Because there was no interaction, the interaction term is dropped and the reduced linear model, shown below, was used to compare the main effects to answer the hypothesis questions.

$$\text{Artillery Kills} = 0.851 + 0.0646\,X_t - 0.394\,X_v$$

The Tactics hypothesis examines if there is a difference in the tactical outcome based on tactical behavior main effect of land-based reconnaissance. Based on the vehicle capabilities and the model, the expectation is that the Aggressive behavior will produce a higher sample mean than the Passive behavior. See Table 5.14.

Table 5.14. Artillery Kills Hypothesis Two: Tactics

Null Hypothesis	H_o: $\mu_{\text{tactics (aggressive)}} <= \mu_{\text{tactics (passive)}}$
Alternative Hypothesis	H_a: $\mu_{t(a)} > \mu_{t(p)}$

The Vehicle hypothesis examines if there is a difference in the tactical outcome based on variant-type while confounding the effects of tactics in battalion sized land-based reconnaissance. For Artillery Kills, the Protect vehicle mean is expected to be greater than the Stealth vehicle sample mean. See Table 5.15.

Table 5.15. Artillery Kills Hypothesis Three: Tracer Variants

Null Hypothesis	H_o: $\mu_{\text{vehicle\_type (protect)}} <= \mu_{\text{vehicle\_type (stealth)}}$
Alternative Hypothesis	H_a: $\mu_{v(p)} > \mu_{v(s)}$

To examine the two hypotheses questions, the reduced general linear model is analyzed. The result of the reduced general linear model is shown in Table 5.16. The test for statistical significance is done first and then the main effects can be compared if there is statistical significance.

Table 5.16: Artillery Kills Reduced Model Results

Predictor	Coefficient	t-value	p-value
Constant	0.851	8.06	0.0000
Tactic	0.0646	1.33	0.186
Vehicle	0.394	-8.13	0.0000

The Vehicle factor has a statistically significant result based on a 95 % C.I. This allows one to compare resulting sample means of the vehicle main effect separately. Table 5.17 shows the results of this comparison.

Table 5.17: Artillery Kills Reduced Model Means Comparison.

Factor	Artillery Kills Sample Mean
Stealth	0.5542
Protect	0.1604

The Artillery Kills MOE data fails to reject the null hypothesis of the Tactics hypothesis that the tactics are the same. The Vehicle hypothesis rejects the null hypothesis showing that the Stealth sample mean is greater than the Protect variant mean.

The results of the reduced general linear model only have an R-squared value of 46.9% with an adjusted R-squared value of 45.5%. The ANOVA results show that vehicles effect on the Artillery Kills. There is no interaction between the two factors--vehicles and tactics.

5.3.4 Scout Direct Fire Kills

The first hypothesis from Chapter Four was that there is interaction between vehicle-type and tactical behavior for Scout Direct Fire Kills MOE of battalion-level, land based reconnaissance. Table 5.18: shows the results of the Scout Direct Fire Kills General Model ANOVA.

Table 5.19. Scout Direct Fire Kills Hypothesis One: Interaction between factors.

Null Hypothesis	H_o: B_1=B_2=B_3
Alternative Hypothesis	H_a: At least one parameter is different.

Table 5.20: Scout Direct Fire Kills General Model ANOVA

Predictor	Coefficient	F-value	p-value
Constant	0.2403		
Tactic	0.2265	160.61	0.0000
Vehicle	-0.0458	6.58	0.0120
Vehicle and Tactics	-0.0430	5.81	0.0180

The Interaction effect p-value of 0.0180 does fall in the rejection region for a 95 % confidence interval. One can reject the null hypothesis that all the parameters are equal in this case. This means that there is interaction between the effects. In the interaction plot in Figure 5.4, one can clearly see that there is interaction.

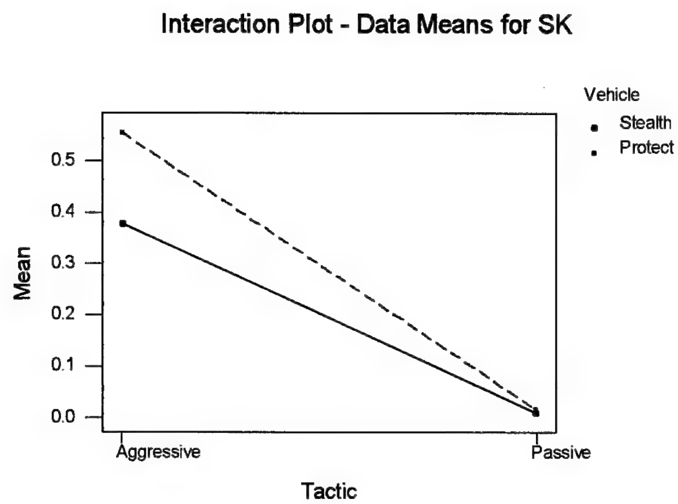

Figure 5.4: Scout Direct Fire Kills Interaction Plot

Interaction leads to the use of the complete general linear model. This allows one to compare the four treatments to each other. The complete general linear model, shown below, is used to compare the interaction effects.

$$\text{Scout DF Kills} = 0.394 - 0.194\, X_t + 0.350\, X_v - 0.172\, X_t\, X_v$$

In Chapter Four, the hypothesis statement was that the Protect/Aggressive treatment would provide the highest scout direct fire kill sample mean. The Stealth/Aggressive would be next, then the Stealth/Passive and then the Protect/Passive. To compare the four factors, the general linear model results are shown below.

Table 5.21: Scout Direct Fire Kills Complete General Linear Model Results

Factor	Scout Direct Fire Kills Sample Mean
Stealth/Aggressive	0.3778
Stealth/ Passive	0.0111
Protect/Aggressive	0.5556
Protect/Passive	0.0167

In this case, the Protect/Aggressive is the best interaction. The Stealth/ Aggressive is the second best, with the Protect/Passive next and the Stealth/ Passive last. The results show that the expectation that Protect/Aggressive would have the highest Scout Direct Fire Kills mean is correct. The only difference is the last two results. The Protect/ Passive comes ahead of the Stealth/Passive for Scout Direct Fire Kills.

The complete general linear result has a high R-squared value of 69.5% with an adjusted R-squared value of 68.3%. The ANOVA result show that vehicles effect on the Scout Direct Fire Kills. In this case, there is interaction between the two factors--vehicles and tactics.

5.4 Summary

The results of this study clearly show that there is little interaction between the vehicle and the tactic used in this scenario. The Direct Fire Kill MOE was the only MOE with statistically significant interaction results. In the next chapter, the conclusions of the study are presented along with lessons learned and possibilities for further research.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The results of the experiment do not show evidence of statistically significant interaction between the vehicle types and the tactics used in this scenario. In retrospect, this is due to similarity in vehicle specifications and necessity to enhance the simulation to capture more of the tactics and advanced system effects. However, the main goal of this research was to present a methodology for the analysis of a weapon system and tactics concurrently early in the acquisition process, not develop the final tactics for the future scout vehicle. Specifically, my goal was to provide a methodology for revising small unit tactics, techniques, and procedures concurrent with the development the material aspect of a new weapon system. Given this scenario and the tactics and vehicles used, there is little interaction. For most MOE's, there was no interaction between the tactic and the vehicle. That does not mean the results would be the same, given another scenario, another set of vehicles, and using different tactics.

By using the lessons learned from this research, more measurement space may be provided by future analysis toward this goal. Whether most constructive simulations are currently robust enough to provide realistic tactical development is still in question. This research does not attempt to answer that question. However, constructive simulation

does offer potential as an analysis tool. It also offers one less costly way to determine how certain combinations of vehicle characteristics and the possible tactics can be explored early in the acquisition process. By developing tactics, or organizational behaviors, in combination with systems concepts during the first phase of the acquisition process, a final product package might include the weapon system and a recommended behavior (e.g. TTPs) to optimize the advances incorporated into the system.

In Chapter One, the general question was advanced, "How might the new weapon system tactical unit behavior developed concurrently with the new weapon system concept take full advantage of that system concept to enhance the tactical outcome?" The research answered this question in the past three chapters by showing one method of varying the tactics with weapon system concepts within constructive simulation.

The main research question arose in Chapter Three: "Is there a difference in tactical outcome due to the use of aggressive or passive land-based reconnaissance by different reconnaissance vehicle systems and can tactics and vehicle systems be developed concurrently?"

The research looked at the following three questions to explore that point,

- Is there interaction between vehicle-type and tactical behavior in the tactical outcome of battalion-level land based reconnaissance?
- Is there a difference in the tactical outcome based on tactical in battalion-level land-based reconnaissance?
- Is there a difference in the tactical outcome based on variant-type in battalion-level land-based reconnaissance?

With all but one MOE, scout direct fire kills, there was no interaction. There are cases where the other two questions were answered, but the main thrust of this research was to show interaction. As a result of this study, one can conclude that there is; little difference in the tactical outcome of the simulation based on variations in vehicle characteristics and tactical behaviors in this particular scenario with these variants using these tactics.

It can not be overstated that the results of this study do not attempt to produce techniques, tactics, or procedures for use in scout platoons in combat. The tactics used in this study are indeed very simple. Instead, this research gives the weapon system developer and the doctrine writer one tool to begin the exploratory process concurrently. This study serves mainly as a demonstration of a concept. The method used to explore the different combinations may be useful in developing future weapons systems and tactics simultaneously in the systems design process. Weapon system acquisition should not logically be accomplished without regard for potential doctrinal change. The challenge for the military is to produce this doctrine through a combination of constructive, virtual, and live simulation in the acquisition process and then provide the soldier and commander with the new doctrine and tactical techniques as the new system is fielded.

6.2 Lessons Learned

There are two immediate lessons learned in this study. First, the vehicles used in this study were very close in capability. This made it difficult to discern a tactical

difference between the forces using different vehicles. The capabilities of the vehicles in this study are two of five variants of the U.S. Army future scout vehicle competition. The two vehicles used in the experiment are the two that best represented the aggressive and passive philosophies within that restricted set. Using the high-end FSV against the current Army scout vehicle or the low-end variant might indicate a greater difference, but these would not have supported the philosophy being investigated. Other choices such as a more robust reconnaissance vehicle, based on the robust capabilities of a modern tank, would better suit the aggressive reconnaissance force. Likewise, a stealthier vehicle could have been contrived.

The second lesson is the difference in the scout tactics. The two scout tactics used in the research were certainly simple, and probably too similar. For example, only the weapons control status served as a basis for the amount of aggressive versus passive behavior. The routes of the scouts were constant, the objectives were the same, and the FSM behavior was the same. The only difference was the weapons control status. Otherwise, the FSV behaviors to be more or less aggressive required rewriting the coded FSM behaviors and external validation of those designs. The actions caused by this setting change does produce a totally opposite behavior--fire at will versus hold fire until fired upon-- but this is a very simplistic model of the true differences between the actions of an aggressive scout and that of the stealthy one.

One idea might be the addition of a finite state machine behavior that one could use to "dial" in a level of aggressive or passive behavior. By changing the scout's tactics

in artillery, main gun fire and tactical movement depending on the variant to study, one might see an increase effect in the overall tactical outcome.

The small amount of difference explained by the LER model in Chapter Five, may be within the normal phenomenon of the scout's true effect on the results of a battle. There are many factors that may share in affecting the outcome of the battle despite the scout's success, in simulation and in reality. Not all variables were accounted for in the research. For example, in ModSAF, the friendly forces simply do not react to friendly unit tactical needs. This is the collective behavior issue mentioned in Chapter Four. The research attempts to adjust the scenario design to account for this issue, but perhaps more adjustments or modifications of automatic responses are required.

There are certainly other variables in the LER model that must be considered. The relative weapon strengths of the opposing forces, their tactical ability and their actions are a few of the possible dependent variables of the LER model that the research does not explain.

In the course of the research, other insights were revealed. In developing several scenarios and new vehicles in the ModSAF environment revealed the complexities of developing simulation scenarios and some of the limitations of current constructive simulation models, specifically in ModSAF. Also the research revealed the limits of this model in its ability to model tactical behaviors. That being said, ModSAF can be a very flexible and capable simulation.

There are two main benefits to this kind of research work. First, future military and the defense industry leaders gain a mutual understanding of the complexities of

warfare and the computer simulation's modeling of combat, respectively, by joint industrial-military studies. The next generation of military leader and corporate executive can only benefit from the understanding gained in such research relationships. As more military doctrine and techniques, tactics and procedures finds its way into the simulation code of semi-automated tactical behaviors, the training and analysis tools effected by simulation may improve, as well.

This leads to the second benefit. This benefit could have enormous effects on the military of the future. As simulations and computer processing speed become more and more complex and fast, the ability to use simulation in real time tactical operations, in battalion tactical mission planning and small unit tactical rehearsal may result in a more capable combat force. Work like this on semi-automated simulation also effects the mechanized forces virtual simulation training realism throughout the military. The Close Combat Tactical Trainer, and other simulations, will soon benefit from the advent of OneSAF, a SAF developed from a ModSAF baseline, to provide a better opponent for the tank crews and infantry squads of the future. The more work on realistic tactical behaviors, the better the opponent for training and the better the tool for analysis.

6.3 Future Research Possibilities

Chapter One also posed the question "How much intelligence in CGF is enough?" There is a continuing requirement by the military and the defense industry to refine and develop the tactical behaviors in constructive simulation models, like ModSAF.

This thesis shows that the inclusion of tactics in the development of alternative weapons systems may offer a useful evaluation on the prospective weapon as a complete tactical system. This research used mostly existing ModSAF tools. The research did not, however, develop an automated collective behavior to study the effects of the tactics on the scout systems' success. This was beyond the available research means. However, this particular area is ripe for further study.

For example, a Tracer system scenario developer could use a finite state machine, like an Advanced Tracer Recon FSM, to allow for slight changes in tactical behavior coupled with the precise changes in scout vehicle weaponry or communication capability in a particular Tracer variant. In a complicated study, this FSM could provide the analyst with less variability in scenario design and allow for slight changes in the system design or tactics in the scenario to determine the effects of those changes on the tactical outcome.

An even more interesting thought is the development of a more cooperative interaction between the scout entities and the recipient of their reconnaissance information. The scout in ModSAF does not communicate the intent metric into task force action, currently, without the aid of the scenario developer. To enable the scout to effect change in the action of a tank company is an exciting idea in constructive simulation.

An Advanced Tracer Recon FSM might include planning tools that could allow a scout to advance to a reconnaissance objective and confirm or deny a commander's priority intelligence requirement (PIR.) The scout entity could then send a confirmation

message to the tank company unit, which would perform a pre-designated action, such as altering main body's course of action through the use of branches to the initial plan. This could increase the systems analyst's ability to more effectively measure the total effect of the scout's success on the success of the main force in a cooperative and semi-automated way.

Another critical areas for improvement in ModSAF is the modeling of vehicle firing signatures and weapons sound effects on combat. As mentioned previously, the ModSAF model does not accurately model the effect of a higher vehicle signature as a vehicle uses its weapons system. The flash and thermal signature caused by a weapon system firing is not modeled. Thus, the firing of a weapon does not increase the probability of another entity detecting the firing vehicle. In a similar vein, the noise created by the weapon does not increase the chances of the firing vehicle to be detected. These are issues that must be addressed to increase the fidelity of the model before tactical doctrine created by the model can be accurately developed.

There may also be further study required into the simulation of C4I and command and control relationships in ModSAF. As the US Army continues to learn more about digital communications and tactical employment of situationally-aware combat units through a series of warfighting experiments, constructive models must be changed to reflect the lessons learned. The current situational awareness and C4I model in Tracer Recon FSM, could be updated to reflect more current information on tactical digital systems, like FBCB2 and IVIS, that are already entering service in the US Army.

APPENDIX A

GLOSSARY

AAFSM- Aggregate asynchronous finite state machine.

AAN- Army after next.

AAAV- Advanced amphibious assault vehicle.

AI- Artificial intelligence.

APC - Armored Personnel Carrier.

AMC- Army Material Command.

ARI- Army research institute.

ARL- Army research laboratory.

ATGM- Anti-tank guided missile.

BN - Battalion.

C2- Command and control.

C4I- Command, control, communication, and information.

CASTFOREM- A high resolution, constructive simulation.

CBS- Corps battle simulation-- a U.S. Army constructive simulation.

CCTT- Close combat tactical trainer--a U.S. Army virtual simulation.

CFF - Call for fire.

CGF- Computer generated forces.

CITV- Commander's independent thermal viewer, a sensor on the M1A2 tank.

COA- Course of action.

CSOP- Combat security outpost.

CTC- Combat training center.

COL- U.S. Army rank of Colonel.

DAS- Distributed Aperture sensor.

DFD- Department of Force Development.

DOD- Department of Defense.

DOTLOMS- Doctrine, training, leadership, organization, materials, and soldiers.

DSB- Defense science board.

DTDD- Department of Tactics and Doctrinal Development.

FBCB2- Forward battle command brigade and below.

FLIR- Forward looking infrared.

FM- Field manual.

FSV- Future scout vehicle.

FSCS- Future scout and cavalry vehicle.

HMMVV- High Mobility Medium V Vehicle.

ICT- Integrated concept team.

IVIS- Inter vehicle information system.

LER- Loss exchange ratio.

M1A2- U.S. Army main battle tank.

M113- U.S. Army armored personnel carrier.

M2A3- U.S. Army personnel carrier and fighting vehicle.

MAJ- U.S. Army rank of major.

MMBL- Mounted maneuver battle laboratory, one of the U.S. Army battle labs.

MNS- Mission needs statement.

MOE- Measure of effectiveness.

ModSAF- Modular Semi-automated forces.

MRC- Motorized Rifle Company.

M3- U.S. Army personnel carrier and fighting vehicle.

NTC- National Training Center at FT Irwin, CA. The U.S. Army CTC in the continental US for mechanized forces.

RSTA- Reconnaissance, surveillance, and target acquisition.

S2- Military intelligence staff officer.

S3- Military operations staff officer.

SA- Situational awareness.

TECO- Test and evaluation command.

TOC- Tactical operations center.

TRAC-WSMR- TRADOC research and analysis center, White Sands missile range.

TRADOC- Training and doctrine command.

TTP- Techniques, tactics, and procedures.

VVS-2- a night vision sensor used for driving tactical vehicles at night.

APPENDIX B

STATISTICS

Summary

In this appendix, the statistical analysis is presented. It is important to note that the research LER MOE includes several outliers. The review of the simulation runs concludes that there are no reasons to discard these runs. The results of these runs have, therefore, been included in the analysis.

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
LER	80	4.896	2.725	3.917	5.829	0.652
Scout Losses	80	0.0563	0.0000	0.0278	0.1778	0.0199
DF Kills	80	0.2403	0.1111	0.2160	0.2837	0.0317
Arty Kills	80	0.3573	0.2917	0.3437	0.2933	0.0328

Variable	Minimum	Maximum	Q1	Q3
LER	0.400	28.000	1.785	5.150
Scout Losses	0.0000	1.0000	0.0000	0.0000
DF Kills	0.0000	1.0000	0.0000	0.4444
Arty Kills	0.0000	1.0000	0.0833	0.5833

General Linear Model for LER

Factor	Type	Levels	Values
Vehicle	fixed	2	1 2
Tactic	fixed	2	1 2

Analysis of Variance for LER, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Vehicle	1	427.07	427.07	427.07	15.52	0.000
Tactic	1	110.17	110.17	110.17	4.00	0.049
Vehicle*Tactic	1	56.72	56.72	56.72	2.06	0.155
Error	76	2090.70	2090.70	27.51		
Total	79	2684.66				

Term	Coef	StDev	T	P
Constant	4.8960	0.5864	8.35	0.000
Vehicle				
1	2.3105	0.5864	3.94	0.000
Tactic				
1	1.1735	0.5864	2.00	0.049
Vehicle*Tactic				
1 1	0.8420	0.5864	1.44	0.155

Unusual Observations for LER

Obs	LER	Fit	StDev Fit	Residual	St Resid
1	26.0000	9.2220	1.1728	16.7780	3.28R
3	28.0000	9.2220	1.1728	18.7780	3.67R
27	25.0000	9.2220	1.1728	15.7780	3.09R
51	28.0000	9.2220	1.1728	18.7780	3.67R

R denotes an observation with a large standardized residual.

Least Squares Means for LER

Vehicle	Mean	StDev
1	7.206	0.8293
2	2.586	0.8293
Tactic		
1	6.070	0.8293
2	3.722	0.8293

General Linear Model for Scout Losses

Factor	Type	Levels	Values
Vehicle	fixed	2	1 2
Tactic	fixed	2	1 2

Analysis of Variance for Tloss, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Vehicle	1	0.03828	0.03828	0.03828	1.55	0.216
Tactic	1	0.00078	0.00078	0.00078	0.03	0.859
Vehicle*Tactic	1	0.01953	0.01953	0.01953	0.79	0.376
Error	76	1.87182	1.87182	0.02463		
Total	79	1.93041				

Term		Coef	StDev	T	P
Constant		0.04063	0.01755	2.32	0.023
Vehicle					
1		0.02188	0.01755	1.25	0.216
Tactic					
1		-0.00312	0.01755	-0.18	0.859
Vehicle*Tactic					
1	1	0.01562	0.01755	0.89	0.376

Unusual Observations for Tloss

Obs	Tloss	Fit	StDev Fit	Residual	St Resid
2	0.50000	0.05001	0.03509	0.44999	2.94R
8	0.50000	0.03751	0.03509	0.46249	3.02R
36	0.50000	0.05001	0.03509	0.44999	2.94R
43	0.50000	0.07501	0.03509	0.42499	2.78R
49	1.00000	0.07501	0.03509	0.92499	6.05R

R denotes an observation with a large standardized residual.

Least Squares Means for Tloss

Vehicle		Mean	StDev
1		0.062509	0.02481
2		0.018759	0.02481
Tactic			
1		0.037509	0.02481
2		0.043759	0.02481
Vehicle*Tactic			
1	1	0.075009	0.03509
1	2	0.050009	0.03509
2	1	0.000009	0.03509
2	2	0.037508	0.03509

General Linear Model for Artillery Kills

Factor	Type	Levels	Values
Vehicle	fixed	2	1 2
Tactic	fixed	2	1 2

Analysis of Variance for AK, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Vehicle	1	3.1008	3.1008	3.1008	66.62	0.000
Tactic	1	0.0834	0.0834	0.0834	1.79	0.185
Vehicle*Tactic	1	0.0730	0.0730	0.0730	1.57	0.214
Error	76	3.5372	3.5372	0.0465		
Total	79	6.7944				

Term	Coef	StDev	T	P
Constant	0.35729	0.02412	14.81	0.000
Vehicle				
1	0.19687	0.02412	8.16	0.000
Tactic				
1	-0.03229	0.02412	-1.34	0.185
Vehicle*Tactic				
1 1	-0.03021	0.02412	-1.25	0.214

Unusual Observations for AK

Obs	AK	Fit	StDev Fit	Residual	St Resid
41	0.91667	0.49167	0.04824	0.42500	2.02R
42	0.08333	0.61667	0.04824	-0.53333	-2.54R
58	0.08333	0.61667	0.04824	-0.53333	-2.54R
70	0.58333	0.16250	0.04824	0.42083	2.00R

R denotes an observation with a large standardized residual.

Least Squares Means for AK

Vehicle	Mean	StDev
1	0.5542	0.03411
2	0.1604	0.03411
Tactic		
1	0.3250	0.03411
2	0.3896	0.03411
Vehicle*Tactic		
1 1	0.4917	0.04824
1 2	0.6167	0.04824
2 1	0.1583	0.04824
2 2	0.1625	0.04824

General Linear Model for Scout Direct Fire Kills

Factor	Type	Levels	Values
Vehicle	fixed	2	1 2
Tactic	fixed	2	1 2

Analysis of Variance for SK, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Vehicle	1	0.1681	0.1681	0.1681	6.58	0.012
Tactic	1	4.1002	4.1002	4.1002	160.61	0.000
Vehicle*Tactic	1	0.1483	0.1483	0.1483	5.81	0.018
Error	76	1.9401	1.9401	0.0255		
Total	79	6.3566				

Term		Coef	StDev	T	P
Constant		0.24028	0.01786	13.45	0.000
Vehicle					
1		-0.04583	0.01786	-2.57	0.012
Tactic					
1		0.22639	0.01786	12.67	0.000
Vehicle*Tactic					
1	1	-0.04306	0.01786	-2.41	0.018

Unusual Observations for SK

Obs	SK	Fit	StDev Fit	Residual	St Resid
15	0.22222	0.55556	0.03573	-0.33333	-2.14R
21	0.88889	0.55556	0.03573	0.33333	2.14R
23	0.88889	0.55556	0.03573	0.33333	2.14R
45	0.11111	0.55556	0.03573	-0.44444	-2.85R
65	1.00000	0.37778	0.03573	0.62222	4.00R
69	0.88889	0.55556	0.03573	0.33333	2.14R
79	0.88889	0.55556	0.03573	0.33333	2.14R

R denotes an observation with a large standardized residual.

Least Squares Means for SK

Vehicle		Mean	StDev
1		0.19444	0.02526
2		0.28611	0.02526
Tactic			
1		0.46667	0.02526
2		0.01389	0.02526
Vehicle*Tactic			
1	1	0.37778	0.03573
1	2	0.01111	0.03573
2	1	0.55556	0.03573
2	2	0.01667	0.03573

Reduced Linear Model for LER

Factor	Type	Levels	Values
Vehicle	fixed	2	1 2
Tactic	fixed	2	1 2

Analysis of Variance for LER, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Vehicle	1	427.07	427.07	427.07	15.31	0.000
Tactic	1	110.17	110.17	110.17	3.95	0.050
Error	77	2147.42	2147.42	27.89		
Total	79	2684.66				

Term	Coef	StDev	T	P
Constant	4.8960	0.5904	8.29	0.000
Vehicle				
1	2.3105	0.5904	3.91	0.000
Tactic				
1	1.1735	0.5904	1.99	0.050

Unusual Observations for LER

Obs	LER	Fit	StDev Fit	Residual	St Resid
1	26.0000	8.3800	1.0227	17.6200	3.40R
3	28.0000	8.3800	1.0227	19.6200	3.79R
27	25.0000	8.3800	1.0227	16.6200	3.21R
51	28.0000	8.3800	1.0227	19.6200	3.79R

R denotes an observation with a large standardized residual.

Least Squares Means for LER

Vehicle	Mean	StDev
1	7.206	0.8350
2	2.586	0.8350
Tactic		
1	6.070	0.8350
2	3.722	0.8350

Reduced Model for Scout Losses

Factor	Type	Levels	Values
Vehicle	fixed	2	1 2
Tactic	fixed	2	1 2

Analysis of Variance for Tloss, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Vehicle	1	0.00313	0.00313	0.00313	0.10	0.756
Tactic	1	0.02812	0.02812	0.02812	0.88	0.352
Error	77	2.46563	2.46563	0.03202		
Total	79	2.49688				

Term	Coef	StDev	T	P
Constant	0.05625	0.02001	2.81	0.006
Vehicle				
1	0.00625	0.02001	0.31	0.756
Tactic				
1	-0.01875	0.02001	-0.94	0.352

Unusual Observations for Tloss

Obs	Tloss	Fit	StDev Fit	Residual	St Resid
2	0.50000	0.08125	0.03465	0.41875	2.39R
6	0.50000	0.06875	0.03465	0.43125	2.46R
8	0.50000	0.06875	0.03465	0.43125	2.46R
14	0.50000	0.06875	0.03465	0.43125	2.46R
16	0.50000	0.06875	0.03465	0.43125	2.46R
36	0.50000	0.08125	0.03465	0.41875	2.39R
43	0.50000	0.04375	0.03465	0.45625	2.60R
49	1.00000	0.04375	0.03465	0.95625	5.45R

R denotes an observation with a large standardized residual.

Least Squares Means for Tloss

Vehicle	Mean	StDev
1	0.06250	0.02829
2	0.05000	0.02829
Tactic		
1	0.03750	0.02829
2	0.07500	0.02829

Reduced Model for Artillery Kills

Factor	Type	Levels	Values
Vehicle	fixed	2	1 2
Tactic	fixed	2	1 2

Analysis of Variance for Tloss, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Vehicle	1	0.03828	0.03828	0.03828	1.56	0.216
Tactic	1	0.00078	0.00078	0.00078	0.03	0.859
Error	77	1.89135	1.89135	0.02456		
Total	79	1.93041				

Term	Coef	StDev	T	P
Constant	0.04063	0.01752	2.32	0.023
Vehicle				
1	0.02188	0.01752	1.25	0.216
Tactic				
1	-0.00312	0.01752	-0.18	0.859

Unusual Observations for Tloss

Obs	Tloss	Fit	StDev Fit	Residual	St Resid
2	0.50000	0.06563	0.03035	0.43437	2.82R
8	0.50000	0.02188	0.03035	0.47812	3.11R
36	0.50000	0.06563	0.03035	0.43437	2.82R
43	0.50000	0.05938	0.03035	0.44062	2.87R
49	1.00000	0.05938	0.03035	0.94062	6.12R

R denotes an observation with a large standardized residual.

Least Squares Means for Tloss

Vehicle	Mean	StDev
1	0.06251	0.02478
2	0.01876	0.02478
Tactic		
1	0.03751	0.02478
2	0.04376	0.02478

Regression Analysis For LER

The regression equation is
LER = 22.9 - 7.40 Tactic - 9.67 Vehicle + 3.37 V_T

Predictor	Coef	StDev	T	P
Constant	22.926	5.864	3.91	0.000
Tactic	-7.399	3.709	-2.00	0.050
Vehicle	-9.673	3.709	-2.61	0.011
V_T	3.368	2.346	1.44	0.155

S = 5.245 R-Sq = 22.1% R-Sq(adj) = 19.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	593.96	197.99	7.20	0.000
Residual Error	76	2090.70	27.51		
Total	79	2684.66			

Source	DF	Seq SS
Tactic	1	110.17
Vehicle	1	427.07
V_T	1	56.72

Unusual Observations

Obs	Tactic	LER	Fit	StDev Fit	Residual	St Resid
1	1.00	26.000	9.222	1.173	16.778	3.28R
3	1.00	28.000	9.222	1.173	18.778	3.67R
27	1.00	25.000	9.222	1.173	15.778	3.09R
51	1.00	28.000	9.222	1.173	18.778	3.67R

R denotes an observation with a large standardized residual

Regression Analysis For Tracer Losses

The regression equation is
Tloss = 0.0969 + 0.0062 Tactic - 0.0438 Vehicle

Predictor	Coef	StDev	T	P
Constant	0.09689	0.07638	1.27	0.208
Tactic	0.00625	0.03504	0.18	0.859
Vehicle	-0.04375	0.03504	-1.25	0.216

S = 0.1567   R-Sq = 2.0%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	0.03906	0.01953	0.80	0.455
Residual Error	77	1.89135	0.02456		
Total	79	1.93041			

Source	DF	Seq SS
Tactic	1	0.00078
Vehicle	1	0.03828

Unusual Observations

Obs	Tactic	Tloss	Fit	StDev Fit	Residual	St Resid
2	2.00	0.5000	0.0656	0.0303	0.4344	2.82R
8	2.00	0.5000	0.0219	0.0303	0.4781	3.11R
36	2.00	0.5000	0.0656	0.0303	0.4344	2.82R
43	1.00	0.5000	0.0594	0.0303	0.4406	2.87R
49	1.00	1.0000	0.0594	0.0303	0.9406	6.12R

R denotes an observation with a large standardized residual

Regression Analysis for Artillery Kills

The regression equation is
AK = 0.579 + 0.246 Tactic - 0.212 Vehicle - 0.121 V_T

Predictor	Coef	StDev	T	P
Constant	0.5792	0.2412	2.40	0.019
Tactic	0.2458	0.1525	1.61	0.111
Vehicle	-0.2125	0.1525	-1.39	0.168
V_T	-0.12083	0.09648	-1.25	0.214

S = 0.2157 R-Sq = 47.9% R-Sq(adj) = 45.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	3.2572	1.0857	23.33	0.000
Residual Error	76	3.5372	0.0465		
Total	79	6.7944			

Source	DF	Seq SS
Tactic	1	0.0834
Vehicle	1	3.1008
V_T	1	0.0730

Unusual Observations

Obs	Tactic	AK	Fit	StDev Fit	Residual	St Resid
41	1.00	0.9167	0.4917	0.0482	0.4250	2.02R
42	2.00	0.0833	0.6167	0.0482	-0.5333	-2.54R
58	2.00	0.0833	0.6167	0.0482	-0.5333	-2.54R
70	2.00	0.5833	0.1625	0.0482	0.4208	2.00R

R denotes an observation with a large standardized residual

Regression Analysis for Scout Kills

The regression equation is
SK = 0.394 - 0.194 Tactic + 0.350 Vehicle - 0.172 V_T

Predictor	Coef	StDev	T	P
Constant	0.3944	0.1786	2.21	0.030
Tactic	-0.1944	0.1130	-1.72	0.089
Vehicle	0.3500	0.1130	3.10	0.003
V_T	-0.17222	0.07145	-2.41	0.018

S = 0.1598   R-Sq = 69.5%   R-Sq(adj) = 68.3%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	4.4165	1.4722	57.67	0.000
Residual Error	76	1.9401	0.0255		
Total	79	6.3566			

Source	DF	Seq SS
Tactic	1	4.1002
Vehicle	1	0.1681
V_T	1	0.1483

Unusual Observations

Obs	Tactic	SK	Fit	StDev Fit	Residual	St Resid
15	1.00	0.2222	0.5556	0.0357	-0.3333	-2.14R
21	1.00	0.8889	0.5556	0.0357	0.3333	2.14R
23	1.00	0.8889	0.5556	0.0357	0.3333	2.14R
45	1.00	0.1111	0.5556	0.0357	-0.4444	-2.85R
65	1.00	1.0000	0.3778	0.0357	0.6222	4.00R
69	1.00	0.8889	0.5556	0.0357	0.3333	2.14R
79	1.00	0.8889	0.5556	0.0357	0.3333	2.14R

R denotes an observation with a large standardized residual

APPENDIX C

INTERVIEWS

Interview with COL Karl J. Gunzelman, Mounted Maneuver Battlespace Lab, FT Knox, KY.

Interview Objective: To determine if the US Army uses constructive simulation in the development and evaluation of tactics, techniques, and procedures (TTP) of new weapons systems.

Sub Objective: Determine the current method for developing TTP the Army uses.

Sub Objective: Determine if constructive and virtual simulations are used in cooperation to develop and evaluate TTP.

Sub Objective: To evaluate the Objective in the opinion of Subject Matter Experts (SME)

Sir, My name is CPT Bill Williams. I am an Armor Captain, a former company commander that participated in the March 97 AWE at the NTC. Before the AWE, I commanded A CO and HHC/ 3-66 AR while stationed at Ft Hood, Texas. I am currently a graduate student at the University of Central Florida, studying for my masters in Simulations and Training Systems. My next assignment is to teach electives on the BOS in the Department of Military Instruction (DMI).

Purpose of this interview, is to gather information for my thesis. I am studying the use of constructive simulation to develop and evaluate small unit tactics of new weapons systems. As part of my study, I am working at the Lockheed Martin Systems Analysis Lab in Orlando, FL with the Tracer / FSV project team.

I would like to ask you for ten to fifteen minutes of your time to interview you on the current uses of simulation in the tactics and doctrinal development at the Mounted Maneuver Battlespace Lab. The results of this interview will be written into the literature review section of my thesis. Sir, if you agree to this interview, you will be cited as a subject matter expert in this area. I would be more than happy to share the results of my study with you upon completion (Mar 1999).

Sir, thank you for your time,

Wilburn C Williams, Jr.
CPT, AR
Graduate Student

Here are the questions I will ask you.

1) Does the U.S. Army use simulation in the development of tactics and doctrine?
Yes. The Mounted Battle Lab, for example, is conducting experiments on 3 tank company battalions and the doctrine that would be used in this case. The battle lab is also conducting constructive simulation on new weapons systems like the FSCS. The FSCS using sensors and calling for TERM fires from the tanks. An experiment in the organization of the new scout platoon and the types and numbers of vehicles is ongoing as is an analysis of what mix of sensors and other capabilities should be on the vehicle. This is part of developing the requirements document of the new system.

2) Is this a formal process documented by an FM or policy? Which one?

Yes, FM 71-9. At FT Knox, the MWBL works with other directorates on post and in the force to develop new ideas and concepts. The DTD send liaisons to the simulation exercises to add tactical ideas. Brainstorming new tactics and then trying them in constructive or virtual simulation is one method used here.

3) How is the Mounted Battle lab connected to the Training and Doctrinal Development Branch in doctrinal development?

We make up two parts of a Future Concept Team. Digital TTP in the M1A2 tank is one collaborative effort.

4) What virtual systems are used to develop doctrine? Which constructive ones? Live?

CCTT. SIMNET. CASTFORM. ModSAF. Janus. Live simulation at the CTC's is used to validate concepts.

5) At what echelon of tactics are simulations used to evaluate new concepts?
PLT, CO, BN, Brigade, higher? And would you mind giving me examples, including the simulation system?

BDE and Below here at the MWBL. Div AWE and Corps exercises are also used to evaluate doctrine.

6) Currently, how does the effect of a new weapon system on current doctrine (tactics) get evaluated?

Simulation has not been used in the past as much. Recently it is being used as a small part of the development process, but money drives the ability to conduct extensive trials.

Simulation based acquisition is growing acceptance.

7) Are experiments set up to evaluate tactics specifically for new weapons systems?

Yes, CEP's concept evaluation program. Battle command reengineering, M1A2 are examples.

8) Is virtual simulation used to *develop or evaluate potential new* TTP or doctrine in conjunction with the new system?

Yes. This is the most used at the MWBL. Human in the Loop allows for the human behavior factor that many constructive simulations lack in fidelity.

9) Do you use constructive simulation to evaluate the capabilities of new weapons systems using new tactics as a factor in the analysis?

Not as you describe. The money and the human in the loop factors, keep the simulation runs small in number.

10) If Yes. Does constructive simulation lead to the development of TTP once a system is fielded?

Yes, but there are many steps in the writing of doctrine at DTD and many factors that go into the writing of this doctrine. Many new weapons systems do not fundamentally change doctrine or tactics. There is no formal systems acquisition and tactics bond because of the many years it may take to field a system. Systems tactics develop over time. Many times after the system has been fielded and used extensively in the field.

11) Has constructive simulation been used to *develop TTP* before using virtual simulation?

Not really extensively. Usually done in conjunction. But, the Model experiment Model approach is being considered.

12) What would concern you most with in developing tactics on constructive simulations? (i.e. Models realistic enough.)

Models are approximations. Live simulation is definitely required before distributing revolutionary tactical changes.

13) Sir, is there anything you would like to add?

No.

Interview with MAJ Phil Johnson, EN, Training and Doctrinal Development

Interview Objective: To determine if the US Army uses constructive simulation in the development and evaluation of tactics, techniques, and procedures (TTP) of new weapons systems.

Sub Objective: Determine the current method for developing TTP the Army uses.

Sub Objective: Determine if constructive and virtual simulations are used in cooperation to develop and evaluate TTP.

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Sir, My name is CPT Bill Williams. I am an Armor Captain, a former company commander that participated in the March 97 AWE at the NTC. Before the AWE, I commanded A CO and HHC/ 3-66 AR while stationed at Ft Hood, Texas. I am currently a graduate student at the University of Central Florida, studying for my masters in Simulations and Training Systems. My next assignment is to teach electives on the BOS in the Department of Military Instruction (DMI).

Purpose of this interview, is to gather information for my thesis. I am studying the use of constructive simulation to develop and evaluate small unit tactics of new weapons systems. As part of my study, I am working at the Lockheed Martin Systems Analysis Lab in Orlando, FL with the Tracer / FSV project team.

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Sir, thank you for your time,

Wilburn C Williams, Jr.
CPT, AR
Graduate Student

Here are the questions I will ask you.

14) How does the U.S. Army currently develop tactics and doctrine?

Army doctrine is established in its field manuals. When the army recognizes a need to establish doctrine, it uses a process to develop ideas and write the doctrine. This process is based on feedback from many sources and ideas from many sources. It can be a set time period review of doctrine or a new technology or threat that drives a doctrinal revision.

In response to a need for a doctrinal revision an Integrated Concept Team is created. There are representatives from the material working group, a group working on systems, and the doctrine working group, the group working on how to employ the system; and other working groups that provide ideas and review based on the need that drives the proposed change. The working groups have sessions that develop into requirement documents. These requirement documents are the baseline for requests for proposals in the acquisition process for new systems or can be a request for a change to a doctrinal manual.

General Officer steering committees review the decisions in of the integrated concept teams and offer experienced views on the changes.

According to the PPT Briefing,

Ground combat vehicle doctrine is developed at Ft Knox, Ft Benning, Ft Sill, Ft L Wood. The doctrinal branch for cavalry systems is Ft. Knox the home of the Armor/Cavalry. The doctrine for the FSCS / FSV will be developed at Ft. Knox and will be incorporated into FM 17-98, The Scout Platoon.

At FT Knox, there are three directorates that report to the Chief of Armor responsible for developing doctrine, new weapons systems, and emerging concepts of mounted warfare. The Directorate of Force Development (DFD) is responsible for new systems. The directorate of Training and Doctrinal Development (DTD) is responsible for doctrinal manuals and training systems. The Mounted Maneuver Battlespace Battle Lab (MMBL) is responsible for emerging concepts and conducts simulations in support of the other two directorates. The MMBL is related to the network of Army Battle Labs.

15) Is this a formal process documented by an FM or policy? Which one?

Yes. TRADOC Pam 71-9.

16) How is the Mounted Battlelab connected to the Training and Doctrinal Development Branch in doctrinal development?

DTD, MMBL, and DFD participate in Integrated Concept Teams to develop concepts from weapons to tactics.

17) What virtual systems are used to develop doctrine? Which constructive ones? Live?

CCTT, SIMNET. ModSAF, Janus. NTC and AWE and other live simulation.

18) At what echelon of tactics are simulations used to evaluate new concepts? PLT, CO, BN, Brigade, higher? And would you mind giving me examples, including the simulation system?

Mostly BDE and below. One concept team was the TERM ammunition for tanks. Another was M1A2. CCTT used. The 3 vs 4 tank platoon experiment used CCTT.

19) Currently, how does the effect of a new weapon system on current doctrine (tactics) get evaluated?

It is a long process. Tactics experiments are conducted like the M1A2 experiment in virtual simulation. Doctrine and tactics evolve over time. Many concepts can come from the field after a system is in use at CTC's and in combat. Some concepts come from the ORD analysis prior to the system development.

20) Are experiments set up to evaluate tactics specifically for new weapons systems? Usually, but they are stand alone.

21) Is virtual simulation used to *develop or evaluate potential new* TTP or doctrine in conjunction with the new system?

Yes. Example an M1 A2 platoon experiment conducted to test the IVIS and CITV effects on fire and movement.

22) Do you use constructive simulation to evaluate the capabilities of new weapons systems using new tactics as a factor in the analysis?

No.

23) If Yes. Does constructive simulation lead to the development of TTP once a system is fielded?

24) Has constructive simulation been used to *develop TTP* before using virtual simulation?

No.

25) What would concern you most with in developing tactics on constructive simulations? (i.e. Models realistic enough.)

Models are not high fidelity enough yet.

26) Is there anything you would like to add?

No.

Thesis Interview Development Sheet

Developed from Frey, Oishi. *How To Conduct Interviews By Telephone and In Person.* Sage Publications. Thousand Oaks, CA, London, England, New Delhi, India. Copyright 1995. PP 43 to 108.

Interview Objective: To determine if the US Army uses constructive simulation in the development and evaluation of tactics, techniques, and procedures (TTP) of new weapons systems.

Sub Objective: Determine the current method for developing TTP the Army uses.

Sub Objective: Determine if constructive and virtual simulations are used in cooperation to develop and evaluate TTP.

Sub Objective: To evaluate the Objective in the opinion of Subject Matter Experts (SME)

Questionnaire Mapping

Related Questions:

Q 1,2,3,4,5,6,7,8,9,10,11,12 Are related to a yes response on the first question.
Q 4,5 are related to a no answer on the first response.

Objective Mapping:

Q 6,7,8,9,10,11,12 are related to the Objective: Constructive simulation in TTP development.

Q 4,5 are relevant to Sub OBJ 1.
Q 6, 7-10 are relevant to Sub OBJ 2.
Q 11,12 are relevant to Sub OBJ 3.

Pretest conducted by:

Name	Time	Notes
1) CPT Sean Pritchard	7 July 1998 1120 ET	- Friendly Interview

Introductory Statement

Sir, My name is CPT Bill Williams. I am an Armor Captain, a former company commander that participated in the March 97 AWE at the NTC. Commanded Tank CO and HHC. 3-66 AR.

I am currently a graduate student at the University of Central Florida, studying Simulations and Training Systems.

Purpose of this interview, is to gather information for my thesis. I am studying the use of constructive simulation to develop and evaluate small unit tactics of new weapons systems.

As part of my study, I am working at the Lockheed Martin Systems Analysis Lab in Orlando, FL with the Tracer / FSV project team.

I would like to ask you for ten to fifteen minutes of your time to discuss current uses of simulation in the tactics and doctrinal development (at the Mounted Warfare Battle Lab/ in the Department of Tactics and Doctrinal Development.)

The results of this interview will be written into my literature review section of my thesis. You, sir, will be cited as a subject matter expert. I would be more than happy to share the results of my study with you upon completion (Mar 1999).

Sir, there are 12 questions that I would like to ask you. Some of these questions may be simple yes or no answers, but feel free to elaborate. I will be writing down your responses so please bear with me. If you would rather answer these questions in more detail, I will take as much of your time as you can spare.

Sir, If you have no questions, may I begin?

27) **Do you use simulation in the development of tactics and doctrine?**
-Yes.

28) What virtual systems are used? Which constructive ones? Live?

- On the Future Scout and Cavalry Vehicle program, we use a combination of virtual and constructive simulation. We use ModSAF as the SAF and reconfigurable simulators for the virtual work.

29) At what echelon of tactics are simulations used to evaluate new concepts? PLT, CO, BN, Brigade, higher? And would you mind giving me examples, including the simulation system?

-We develop the simulations at the platoon level because of the scale of a virtual experiment. The bigger the experiment the more assets are required. We are testing new systems. Therefore the tactics are not the end state, but we do try to adapt the tactics to the systems capability. At the new vehicle system level, we are testing the differences in different sensors and weapons on mission success.

-We are using the brigade recon troop as one model unit. A recent experiment studied the use of robots in conjunction with the FSCV. We conducted 24 virtual runs total. This included a few runs on each vehicle

-Even though we had a draft set of TTP, that we had thought up, the crews moved away from the draft TTP in the simulation as they performed the mission. Most of the time the crews used current tactics.

Why?

-The crews are trained in current tactics and gravitated back to them under stress.

30) Currently, how does the effect of a new weapon system on current doctrine (tactics) get evaluated?

- We use the after action review (AAR) process and evaluate the system according to current or draft TTP. It is subjective to the experience of the evaluators. We use kill ratios sometimes, but we have a low number of runs.

31) Are experiments set up to evaluate tactics specifically for new weapons systems?

-No, a series of issues are evaluated once. We did some experiments on the three or four tank platoon to see if current tactics were still useful.

32) Is virtual simulation used to *develop or evaluate potential new* TTP or doctrine?

-Yes. It is more useful. ModSAF is difficult to program behaviors. Some behaviors are not realistic. Real soldiers can operate the new systems through simulation and provide realism that ModSAF can not.

33) Do you use constructive simulation to evaluate the capabilities of new weapons systems?

- Yes, they are used in conjunction with the virtual simulations as the drivers of the enemy forces and to provide the battlefield effects and environment to the virtual simulations.
The runs are not sufficient to provide statistically valid results, though.

34) If Yes. Does constructive simulation lead to the development of TTP?

No, the draft TTP was created by myself and a committee from the Tactics Branch at Ft Knox. It was a brainstorm team effort. No, simulation of the tactics were done to assist the process.

35) Has constructive simulation been used to *develop TTP* before using virtual simulation? (Multiple Runs to gain validity, than validating using virtual simulation experiments?)

-No. Not that I have seen, but I have not been here at the MMBL over a year.

36) (If no) Do you see a use for this idea in doctrinal development?

-Yes. It is a good idea, you could look at broad tactical questions such as passive vs. aggressive reconnaissance, for example.

-An iterative process using tactics developed to the systems and conforming the systems to the tactics would be a great idea.

37) What would concern you most with in developing tactics on constructive simulations? (Models realistic enough)

-Lack of soldiers in the loop, real people vs. model behavior
-ModSAF's realism
-Can be useful
-Money to perform the experiment

38) Sir, is there anything you would like to add?

-No

Sir, I appreciate you time. Do you mind if I contact you for any follow up question in the course of my thesis work? I will make arrangements through a POC. Thank you, sir.

Interview with CPT Dan Ray

16 July 1998 1100 ET

In an interview with CPT Dan Ray, I confirmed and clarified his paper on the June experiment with Battle Command. I also used this interview to help construct the survey questionnaire for COL Gunzelman and selected members at the MMBL.

I asked CPT Ray if constructive simulation was being used at the MMBL to develop doctrine. He stated that most experiments used human-in-the-loop or virtual simulation coupled with constructive simulation that provided the environment and semi-automated forces. Some experiments were designed to develop tactics, like this Battle Command Army After Next (AAN) experiment in June, but constructive simulation was not used to help develop the tactics before the virtual simulations.

In new weapons experiments, constructive simulation was not used to develop tactics prior to virtual runs. He gave me the names of several points of contact in the future scout cavalry vehicle (FSCV) program. He mentioned that the tactics developers at the Department of Doctrine and Training (DTDD) did not participate much in the tactics development of the new weapons systems. He said that they were more concerned with near term and current doctrine.

I reviewed my interview questions with him and he helped me refine them to their current state.

LIST OF REFERENCES

Craft, Michael A. and Karr, Clark, R. (1996) *Testing Future Weapons Systems Using CGF Systems.* Proceedings of the Sixth Conference on Computer Generated Forces and Behavioral Representation. Institute For Simulation and Training. Orlando, FL.

Coe, Gary, Madden, James, Mengel, Larry, and Wright, Richard (1997) *Virtual Simulation Support to the 1996 Defense Science Board Summer Study: "Tactics and Technology for 21st Century Military Superiority."* Institute for Defense Analysis. (IDA D-1988). Alexandria, VA.

Diehl, James, MAJ. (1988). *Who is Out There? Tactical Reconnaissance Formations for the Heavy Division.* Unpublished monograph, School of Advanced Military Studies. U.S. Army Command and General Staff College, Fort Leavenworth, KS.

Department of Defense. (1995) (a) *DOD Dictionary of Military Terms.* (Joint Publication 1-02). Washington D.C: Author.

Department of Defense. (1995) (b) *Modeling And Simulation (M&S) Master Plan.* (DOD Directive 5000.59-P). Washington D.C: Author.

Goldsmith, Martin and Hodges, James(1987). *Applying the National Training Center Experience: Tactical Reconnaissance.* The RAND Corporation, (N-2628-A). Santa Monica, CA.

Gunzelman, Karl, COL (1998, OCT 26). Interview with Director, MMBL. Unpublished Interview.

Headquarters, Department of the Army. (1994). *Scout Platoon*. (FM 17-98). Washington, DC: Author.

Headquarters, Department of the Army. (1995) (a). *Force XXI Operations*. (TRADOC Pamphlet 525-5). Washington, DC: Author.

Headquarters, Department of the Army. (1995) (b). *Operations*. (FM 100-5). Washington, DC: Author.

Headquarters, Department of the Army. (1996) (a). *Cavalry Operations.* (FM 17-95). Washington, DC: Author.

Headquarters, Department of the Army. (1996) (b). *Tank Platoon*. (FM 17-15). Washington, DC: Author.

Headquarters, Department of the Army. (1998, September-October) (a). Exploiting Precision Maneuver: An Experiment to Evaluate M1A2 Tactics, Techniques and Procedures. Prepared by PLT/CO/BN Branch, Doctrine Division, DTDD, Armor, CVII-5, 44-47.

Headquarters, Department of the Army. (1998) (b). *Force Development Requirements Determination*. (TRADOC Pamphlet 71-9). Washington, DC: Author.

Headquarters, Department of the Army. (1998) (c). TRADOC Battle Labs Homepage. Battle Labs: Defining the Future. Available: http://battlelabs.monroe.army.mil/blitcd/Briefing/index.htm)

Hoff, Bruce and Lee, Craig. (1998) *Task Organization for Simulated Marine Exercises in CFOR and ModSAF.* Proceedings of the Seventh Conference on Computer Generated Forces and Behavioral Representation. Institute For Simulation and Training. Orlando, FL.

Isby, David C. (1981) *Weapons and Tactics of the Soviet Army*. London, UK: Jane's Publishing Company Limited.

Johnson, John. (1958) *Analysis of Image Forming Systems.* Image Intensifier Symposium. Fort Belvoir, VA 6-7 October 1958.

Johnson, Phil, MAJ (1998, OCT 26). Interview with Senior Doctrine Writer, DTDD. Unpublished Interview.

Kelton, D., Sadowski, R., and Sadowski, D. (1998), Simulation with Arena. Boston, MA: WCB McGraw-Hill.

Lartigue, Louis. (1998) *Extending the Evaluation of Tactical Reconnaissance in Simulation Through the Demonstration of Intent.* Unpublished Master's Thesis, University of Central Florida, Orlando, FL.

Loral (1993). *ModSAF: Software Architecture Design And Overview Document.* Loral Advanced Distributed Simulation, Cambridge MA.

Lovaszy, Steven. (1996). *Comparison of Bradley M2A2 and M2A3 Using JANUS.* Unpublished master's thesis, Naval Postgraduate School, Monterey, CA.

Mackey, Douglas, Dixon, David, Jensen, Karl, Loncarich, Thomas, and Swaim, Jerry. (April 1994), CASTFOREM. Combined Arms and Support Task Force Evaluation Model) Update: Methodologies. DEPARTMENT OF THE ARMY. US ARMY TRADOC Analysis Center. (TRAC-WSMR-TD-94-010.) White Sands Missile Range, NM.

Matsumura, John, Steeb, Randall, Herbert, Thomas, Lees, Mark, Eisenhard, Scot, and Stich, Angela.(1997). *Analytic Support to the Defense Science Board: Tactics and Technology for the 21st Century Military Superiority.* Documented Briefing. The RAND Corporation, (DB-198-A). Santa Monica, CA.

McCarthy, Thomas, LTC. (1994). *U.S. Army Heavy Brigade Reconnaissance During Offensive Operations.* Unpublished monograph, School of Advanced Military Studies. U.S. Army Command and General Staff College, Fort Leavenworth, KS.

Ray, Daniel, CPT (1998). Battle Lab Experiment Plan (BLEP) for Battle Command Reengineering Concept Experimentation Program (CEP) #1701. Unpublished paper. Mounted Maneuver Battlespace Lab, Fort Knox, KY.

Rajput, Sumeet and Karr, Clark, R. (1996). *A New Mechanism for Cooperative Behavior in ModSAF.* Proceedings of the Sixth Conference on Computer Generated Forces and Behavioral Representation. Institute For Simulation and Training. Orlando, FL.

Proctor, M. (1996) "Simulation Definitions." Unpublished Class Notes, University of Central Florida, FL.

Savetti, J.L. (1994). *Comparison of the Future Scout Vehicle Using JANUS(A) High Resolution Combat Model.* Unpublished master's thesis, Naval Postgraduate School, Monterey, CA.

Sobey, Thomas. (1995). *Creation of A Computer Generated Semi-Autonomous Entity Able to Function in an Amphibious Environment.* Unpublished master's thesis, Naval Postgraduate School, Monterey, CA.

Steeb, Randall, Matsumura, John, Covington, Terrell, Herbert, Thomas, Eisenhard, Scot, and Melody, Laura.(1996). *Rapid Force Projection Technologies: A Quick-Look Analysis of Advanced Light Indirect Fire Systems.* Documented Briefing. The RAND Corporation, (DB-168-A). Santa Monica, CA.